VOL. IV NO. 5

Engineering Library
GENERAL LIBRARY
MAY 15 1919
UNIV. OF MICH.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

MAY 1919

SUMMER MEETING
OTTAWA BEACH, MICHIGAN
JUNE 23-27

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

They selected NON-GRAN for this 20-ton Bliss Press

IT'S just another instance of their wanting the best—and naturally they took Non-Gran.

Why?

They killed two birds with one stone.

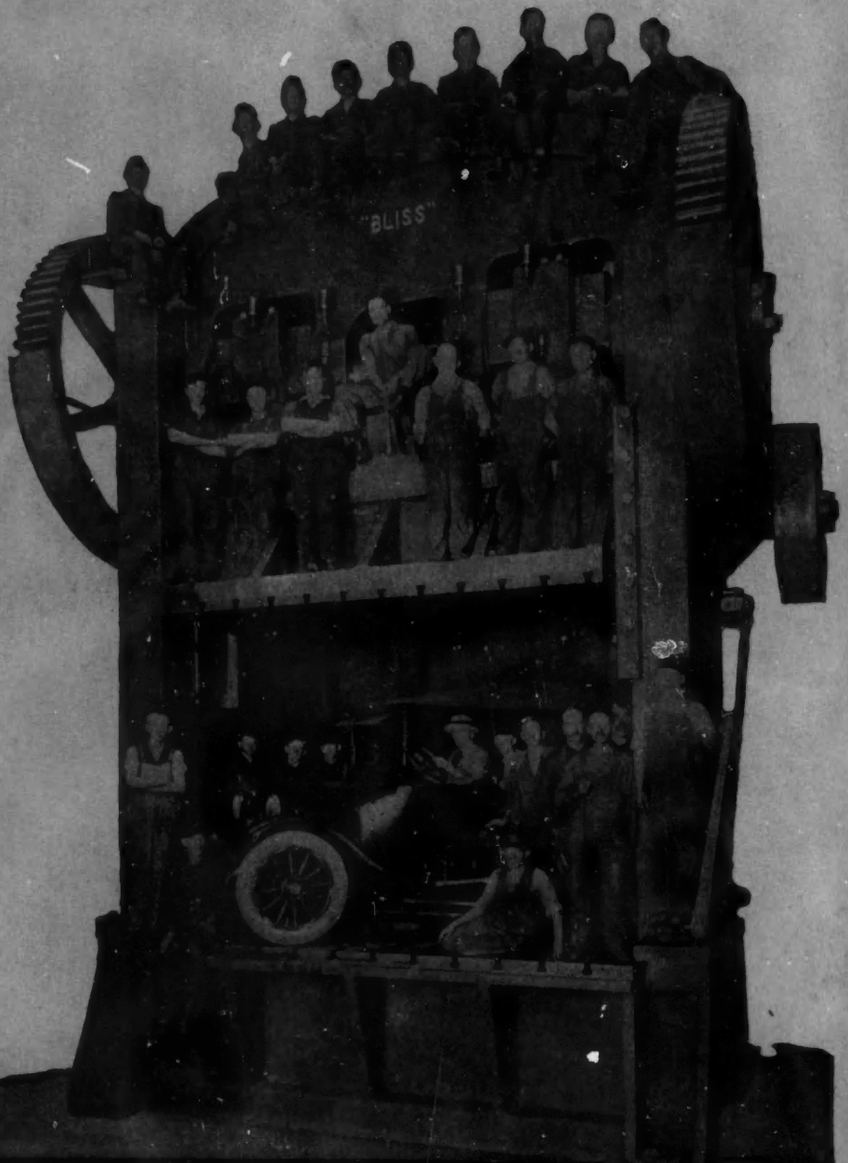
Safety first and resistance to wear.

All users of large presses know the human risks, and are first concerned in safety to operators—then losses in production when the machines are down for repairs and no longer earn money, but cost money.

The maintenance of maximum production for the longest possible time has been accomplished again and again by Non-Gran—and after other bearing bronzes have failed to stand up under the grind of friction.

Non-Gran costs more per pound than inferior bearing metals, but the difference is more than counter-balanced in keeping your machines on the job at maximum output.

American Bronze Corporation
Berwyn Pennsylvania



HIGH SPEED

NON-GRAN

BEARING BRONZE

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. IV May 1919 No. 5

SUMMER MEETING OF THE SOCIETY

OTTAWA BEACH, JUNE 23—27

IT has been definitely decided to hold the Summer Meeting of the Society at the Hotel Ottawa, Ottawa Beach, Mich., June 23 to 27 inclusive. The meeting will start on Monday, and continue until Friday evening.

This decision has been arrived at after extensive consideration of many proposals concerning time and place, and a canvass of many members located in nearly all sections of the country. Among the reasons for selecting Ottawa Beach are the following: Facilities are excellent for holding a meeting combining both recreational and professional features, a condition which a large majority of the members favor. The location is as central as any suitable place known to be available. It is readily accessible from most automotive centers, and can be reached by boat (from Chicago), by rail and by automobile.

Ottawa Beach is located on the eastern shore of Lake Michigan approximately 100 miles northeast of Chicago, and about 30 miles southwest of Grand Rapids. While the beach proper is situated on Lake Michigan, the hotel faces Black Lake, and is adjacent to an inlet connecting the latter with Lake Michigan. The hotel is on the north side of the inlet and a summer resort, known as Macatawa Park, is located on the south side. Black Lake lies east of these two settlements and forms what is virtually a harbor 6 miles long. At the eastern end of Black Lake is situated the town of Holland from which there is direct connection by steamer with Chicago. Holland is on the main line of the Pere Marquette Railroad, 152 miles from Chicago and about 25 miles southwest of Grand Rapids. Macatawa and Grand Rapids are connected by an electric railway which passes through Holland. The Hotel Ottawa is owned by the railroad company which has guaranteed special service for members attending the Summer Meeting. Each member will shortly be furnished a map showing the precise location of the hotel with automobile roads, trolley lines, railroads and boat connections.

The Hotel Ottawa provides excellent accommodations for 700 to 800 guests, and adjacent cottages and other nearby hotels will if desired enable double this number to be taken care of. Application forms for hotel reservations will be sent all members shortly, with particulars concerning rates, location of rooms, etc. Members of the Society, their families and guests will be accorded exclusive use of the hotel facilities.

The professional program is expected to include papers on most if not all the principal branches of automotive engineering, but the number of papers to be presented will be limited so as to permit thorough discussion, and every effort will be made to have a meeting of such profit that no automotive engineer can afford to be absent.

Among the subjects to be discussed are the Design of the Future Passenger Car, Production in its Various Aspects, Tractors, Trucks, Aircraft, Motor Boats, Stationary and Farm Engines, and probably Motorcycles, Fuels, and Materials of Engineering.

The meeting will include the usual convention of the Standards Committee, with ample opportunity for consideration of the reports of its various Divisions. There will also be a business session at which topics of importance to the Society will be discussed. Among the reports to be submitted at this meeting will be one from the Meetings Committee concerning the policy to be followed in connection with summer meetings of the Society during the next several years. Some members have expressed a desire to have arrangements brought about for an engineering exhibit of automotive parts to be held in connection with S. A. E. Summer Meetings. Members will be given an opportunity to express their views on this subject, concerning which there is a considerable diversity of opinion.

It is intended that the Summer Meeting shall pro-

vide above all opportunity for members and guests of the Society to become better acquainted. To this end numerous social and sporting events are being arranged, and it is planned to have professional sessions during mornings only. In the afternoons there will be arranged many demonstrations of automotive apparatus somewhat similar in nature to those which proved of such great interest at the meeting of the Society held at Dayton last summer. These are expected to include many flights of seaplanes and flying boats, as well as of several varieties of airplanes and airships. It is expected that there will also be races of high-speed motor boats, and demonstrations of tractors in operation will probably be arranged if suitable fields for this purpose can be secured. During the evenings there will be staged popular lectures on scientific, engineering and other subjects. These will be well illustrated and of such a nature as to interest both men and women. There will also be dancing each evening and specially selected motion pictures of interest to all.

There will be opportunity for golf, tennis, baseball and all kinds of aquatic sports. Special tournaments and races for which suitable prizes are to be provided will be arranged.

From the foregoing it will be clear that the meeting is intended to be in the nature of an outing as well as a professional gathering. It is hoped that members will arrange to bring their families. A program of events of particular interest to ladies will be scheduled, and no stone will be left unturned to make the meeting as a whole the most profitable and interesting in the history of the Society.

POSITIONS AND MEN TO FILL THEM

DURING the present period of readjustment the Society is particularly desirous of being of service both to the automotive industries and to its members, many of whom have been or are still in the Government service but will shortly return to commercial pursuits.

Members and the companies they represent can do the Society, themselves and their fellow members a real service by informing the S. A. E. office promptly of any openings for men of engineering or related experience which come to their notice. The S. A. E. employment service is intended to benefit all who make use of it. It helps the right man to connect with the right job, and makes absolutely no charge to either employer or employe. Members who desire a change of occupation and companies who need new men are accorded free use of the Men and Positions Available Columns in the advertising section of THE JOURNAL, but the man and the job are frequently brought together through correspondence with the S. A. E. office without any printed notice appearing. Members are therefore urged to write the Society immediately when new men are needed, and also to request company employment managers to do likewise.

While many of the members registered with the Society as available are men of considerable experience, there are also many prepared to accept subordinate positions. It should be borne in mind that the membership of the Society includes men holding such positions as the following in each of the automotive industries, viz.: aeronautic, automobile, marine, farm and stationary engine and tractor, as well as in related industries furnishing materials, parts and accessories, and that the employment service is intended to cover these and other of the various pursuits followed by S. A. E. members.

Assistant Engineer
Chemist
Chief Engineer
Consulting Engineer
Designing Engineer
Draftsmen of all grades
Electrical Engineer
Executive
Executive Engineer
Experimental Engineer
Foreman of Tests
Fuel and Lubricant Specialist
Inspection Engineer
Instructor
Laboratory Assistant
Laboratory Engineer
Lubrication Engineer
Maintenance Engineer
Managers of Plant Departments
Mechanical Engineer
Metallurgical Engineer
Operating Engineer
Production Engineer
Patent Attorney
Plant Engineer
Professor of Engineering
Purchasing Agent
Research Engineer
Sales Engineer
Sales Manager
Service Engineer
Shop Men
Superintendent of Plant
Tire and Rubber Specialist
Tool Designer

CUBAN ENGINEERING ASSOCIATION FORMED

THE Association of Members of American National Engineering Societies in Cuba has been formed with headquarters at Havana. Persons who are members of the American national engineering societies are eligible for membership in the Association. Four regular meetings are scheduled for each year at which members are invited to present papers and discussions of engineering interest and additional special meetings may be called by the president from time to time if found necessary. Further information regarding the Society and application blanks for membership can be secured by addressing the secretary, T. Carlile Ulbricht, Empedrado No. 17, Havana, Cuba.

High-Speed High-Efficiency Engines

By D. McCall White[1] (*Member*)

Annual Meeting Paper *Illustrated with* Photographs and Charts

ENGINEERS have different ideas regarding engines of high efficiency and moderately efficient engines. For very high-speed engines, the designer must not lose sight of the fact that what the public requires today is a small engine which has good torque at low speeds and is capable of revolving efficiently at very high speeds. These two points are difficult enough to attain together, as one is really opposed to the other in practice, due to the fact that to obtain high speeds with power, the valve areas, valve ports, carbureter, etc., must not be restricted in any way whatever; while, to obtain a good mixture at low speeds with heavy torque, means, first, a different valve-setting, and, second, more or less restricted port and valve areas, etc., to give high gas velocities. If one adds to the above complications the fact that it is also required that the modern valve gear be silent, the proposition is one which calls for considerable thought and ingenuity.

Briefly stated, the fundamental of high-speed engines is as follows:

High mean effective pressures at high speeds, which depends on: (1) high volumetric efficiency; (2) high compression to aid in obtaining rapid combustion at high speeds, and (3) light reciprocating and rotating parts to obtain high mechanical efficiency.

It is only a few years since engines were designed with a maximum power at 1200 to 1500 r.p.m., although some designers had the forethought to consider that it was possible to attain very high engine speeds indeed, and today this is an accomplished fact.

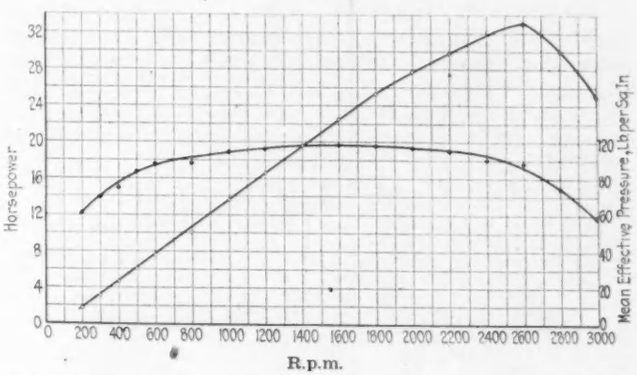
The high-speed, high-efficiency engine of today must be designed very carefully indeed to obtain good results, as one slip will spoil the whole design entirely. We have all lengths of stroke to bore ratios, but in my opinion the stroke-bore ratio should be between 1.5 to 1 and 1.625 to 1, because one can obtain all the power required without having a very unwieldy and heavy engine.

It should also be considered that there are more fastidious purchasers than ever today, and therefore there must be no doubt whatever that the engine must be practically free from vibration and be most sweet, silky and silent when delivering power. In short, the saleable article, it appears to me, is the one which has small size coupled with great power and is neat and compact in design, with the requisite silence. There is nothing that pleases the owner more than this combination.

I have mentioned many times that a bore of approximately 90 mm. is about the maximum cylinder size for high-speed work, and after that I certainly believe multiplicity of cylinders should commence.

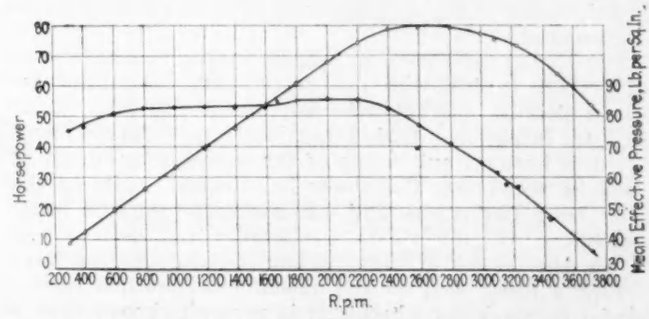
Mean Effective Pressures

In my opinion it is quite useless to think of designing an engine to cope with the present-day market unless it can develop power up to from 2500 to 3500 r.p.m. or over, smoothly and quietly. The power must be good and a touring car engine of today must be capable of carrying a mean effective pressure of from 80 to 100 lb. per sq. in. relative to the brake horsepower up to 2200 r.p.m. at least. A power and mean effective pressure curve of a 12-hp. Napier engine designed in 1911, having one L-head exhaust valve and one overhead intake valve immediately above, might be of interest. This engine was a four-cylinder, 2 11/16-in. bore by 5-in. stroke, and showed a mean effective pressure relative to the brake of 98 lb. per sq. in. at 1400 to 1800 r.p.m. and a maximum of 33 b.hp. at 2600 r.p.m. This engine was fitted with a muffler but naturally pulled more power without the muffler. It has a two-jet carbureter of my own design. The crankshaft had two bearings and had forced lubrication throughout. A mean effective pressure and power curve of the standard Cadillac eight-cylinder engine run up to the very high speed of 3750 r.p.m. is of considerable interest.



Brake Horsepower and Mean Effective Pressure Curves for a Four-Cylinder Engine Having an L-Head Exhaust Valve with a Single Intake Valve Directly Above

The accompanying table shows the bore and stroke of seven different engines with the revolutions per minute



Brake Horsepower and Mean Effective Pressure Curves of an Eight-Cylinder Passenger Car Engine

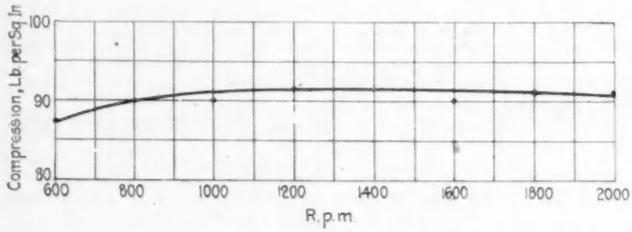
[1]Vice-president, Cadillac Motor Car Co., Detroit, Mich.

and mean effective pressure relative to the brake, which I obtained from them some few years ago.

Bore, mm.	Stroke, mm.	Speed r.p.m.	Mean effective pressure, lb. per sq. in.
68.0	127	2,400	89.0
68.0	127	2,000	97.5
82.5	127	1,200	82.5
89.0	127	1,200	79.5
96.0	130	1,200	127.0
80.0	130	3,000	103.0
80.0	130	2,400	104.0

Volumetric Efficiency

To design a successful high-speed engine, it is desirable that the compression should be fairly high in order to get rapid combustion at high speeds; the clearance space should approximate 21 per cent of the total volume. A compression curve of the Cadillac eight-cylinder engine will be of interest as showing how the compression pressure is maintained at over 90 lb. from 800 to 2000 r.p.m.



Compression Curve of an Eight-Cylinder Passenger Car Engine

A very simple and easy method of measuring the compression pressure, as well as the maximum pressure in an engine cylinder is by the use of the Okill indicator, an English instrument which we have found to be very satisfactory indeed.

The high-speed engine might be likened to an air compressor, as the great point is to get the charge into the cylinders and thus obtain the highest possible volumetric efficiency, and much can be done by the shape and smoothness of the pipes, lack of bends or elbows, particularly careful design of valve ports, seats, etc., together with their cooling. As is well known, the volumetric efficiency is entirely dependent upon port area, large carbureters, large valves, etc., but coupled with these advantages is the obvious difficulty of securing proper carburetion and of starting in cold weather, the former of which affects the acceleration to a very great degree. As cold weather is with us every year, it is highly important that precautions should be taken by designers to see that their enthusiasm for maximum power does not overstep the bounds of proper carbureter size, etc., in order to get a combination of highly satisfactory running both summer and winter.

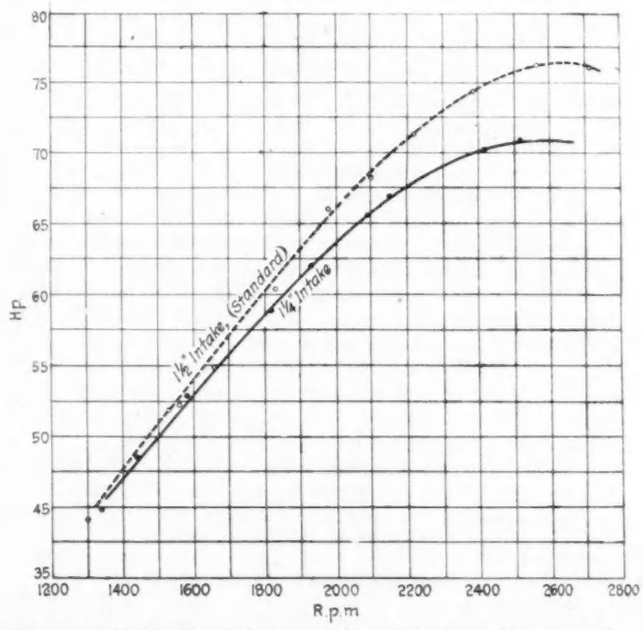
Much has been done in heating intake manifolds, and I propose to deal with this point later. The difference on a Cadillac eight-cylinder engine in 1915 when using 1¼-in. intake manifold, as against 1½-in. intake manifold, is brought out in one of the curves reproduced. It will be noted that the power is increased right up the line from 1200 r.p.m. and was about the same at lower speeds.

On the matter of high volumetric efficiency, we have heard a great deal on the question of multiple valves, and I do not know whether it is generally known that a group of three intake valves was used in the English Napier car in 1909. If I remember correctly, this feature was described in *The Autocar* around that time. Much has been heard of the overhead valve, and many types of overhead valve systems have been used. We have seen racing cars with overhead camshafts driven by bevel, spur or spiral gears, etc., and other valve systems with the camshaft below and push-rods with rockers operating the valves above, but I do not believe that it is possible to design a satisfactory and quiet overhead valve mechanism with a combination of rocker-arms and overhead camshafts, because of the difficulty in obtaining quiet engines. On the other hand, we have a quieter system with the camshaft below and push-rods coupled with rocker-arms operating the valves above, but I believe that the inertia of this valve mechanism would be so great as to almost put it out of count as the kind of a valve gear that should be designed into a high-speed engine.

Valve Gear Types

When all is said and done, there is a great deal to be said for the L-head type of engine, because the valve gear can be kept down very light indeed, very good sized valves can be used, and it is a fact that this, up until the moment, is the quietest type of valve gear which can be used in the touring car engine. It is true that the engine fitted with overhead valves when properly designed should pass approximately 25 per cent more gas than the L-head engine, although a well designed L-head engine uses about 75 per cent of the circumference of the valve, while with the T-head engine only about 50 per cent of the circumference of the valve is effective. Where multiple valves are used, it is very easy to see by simple calculation that the frictional resistance offered by double valves and ports is approximately 30 to 35 per cent greater than that of a single valve and port of the same area.

On the question of the inertia of valve mechanism generally, in the Cadillac eight-cylinder high-speed engine of today we are obtaining engine speeds on the road of well over 3000 r.p.m. and have records of 3550 and 3850



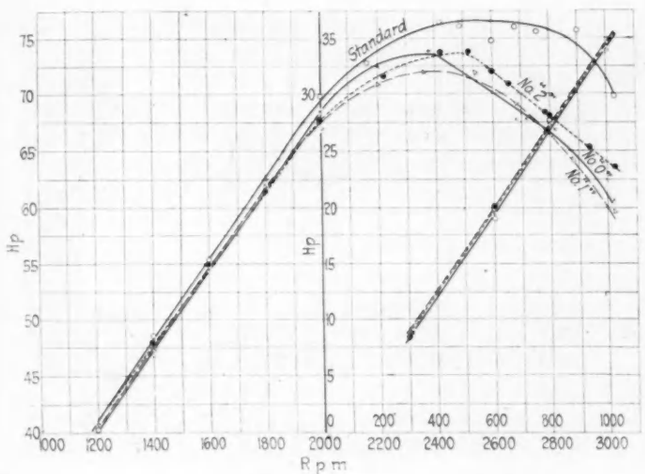
Increased Power Developed by an Eight-Cylinder Passenger Car Engine when Equipped with a Larger Intake Manifold

r.p.m. road performance. If one considers that at 3000 r.p.m. the time taken to open and close one of the valves is 0.0125 sec. at 3550 r.p.m. 0.0106 sec., and at 3850 r.p.m. 0.0098 sec., one sees that in a very high-speed engine the time allowed for a valve to open and close is extremely short.

At various times there have been discussions regarding the different angles for valve seats, and if one takes a seat of 50-deg. angle have a supposed lift of ¼ in., this will give a valve area across the narrowest portion of only 72 per cent of ¼ in.; while, if the valve seat having the same width of seat as the 50-deg. seat is 30 deg., this gives 87.5 per cent of ¼ in.; while the 30-deg. seat narrowed down to around 1/16 in. gives the same amount of ¼ in., but, of course, gives a larger valve bore, thus decreasing the velocity through the bore itself.

Valve-Timing

The valve-timing of an engine has, of course, considerable effect on the power, not only at low but also at high speeds. We ran some power curves on the Cadillac 1916 eight-cylinder engine at that time, all of these tests being



Effect of Changes in Valve-Timing upon the Power Developed by an Eight-Cylinder Passenger Car Engine

run on the same engine, and the superposed curves are reproduced. The following timing is that given in the chart.

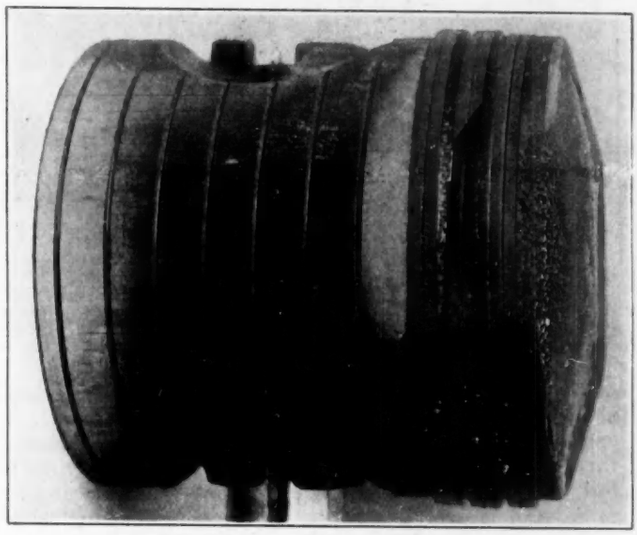
	Inlet opens	Inlet closes	Exhaust opens	Exhaust closes
Standard timing	3° 49′(A)	47° 29′(A)	46° 56′(B)	3° 7′(A)
No. 0 timing	1° 52′(A)	31° 22′(A)	47° 52′(B)	1° 49′(A)
No. 1 timing	2° .. (B)	32° 19′(A)	47° .. (B)	1° 10′(A)
No. 2 timing	1° 22′(A)	33° 7′(A)	43° 30′(B)	2° .. (A)

Inspection of these superposed power curves will show a slight gain up to 1000 r.p.m. in favor of the last three valve-timings, but after that point there is a slow and steady loss up to 2400 r.p.m., where there is a sudden break in the curves, while the curve run with the standard timing shows practically no loss of power up to about 2800 r.p.m.

Valve Material

The material used in valves is very important indeed. In England, around 1913, when running with engines turning up as high as 3800 r.p.m., I used materials having the following analyses according to the speed at which the engine was to run:

Speed, r.p.m.	3,800 Per cent	3,000 Per cent
Carbon	0.400	0.320
Silicon	0.140	0.100
Sulphur	0.030	0.030
Phosphorus	0.035	0.037
Manganese	0.650	.....
Nickel	5.000	3.000



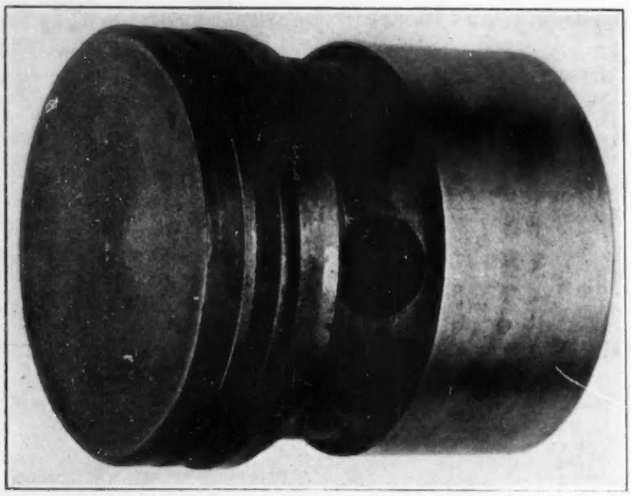
A Liberty-Twelve Aluminum Alloy Piston Showing the Corrosion Resulting from the Continuous Changing of Temperature and Quality of the Air-Fuel Mixture

While both analyses were satisfactory, we always had more or less trouble with warping and consequent compression leakage, etc. The analysis of the valves used in the Cadillac eight-cylinder should be of interest, as we have practically no trouble so far as our valves are concerned. The accompanying analysis are used:

	Intake Valve Per cent	Exhaust Valve Per cent
Carbon	0.690	0.560
Manganese	0.320	0.350
Sulphur	0.012	0.016
Chromium	1.080	3.060
Tungsten	2.150	13.840
Vanadium	0.080	.....
Silicon	0.150	0.170
Nickel	0.150	0.120

Pistons

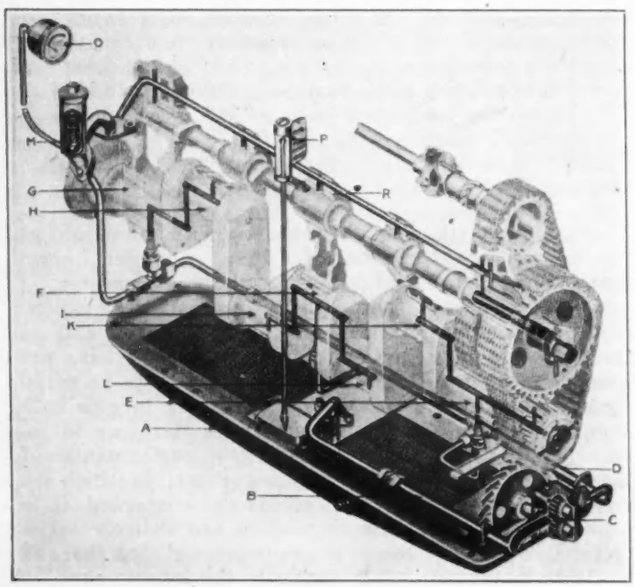
I have already laid considerable stress on the weight of the valve mechanism, and, of course, it is well known that the pistons should be just as light as possible. I have tried various designs of pistons, including aluminum, steel and cast iron of all different shapes, and, so far as the touring car engine is concerned, I have not found either the aluminum or steel pistons to be satisfactory. In the first place, it is necessary to give both aluminum and steel pistons very large clearance to insure quiet running and satisfactory performance of the engine. Where aircraft engines or engines which are continually running at high speeds are concerned, it is possible that the aluminum pistons are entirely satisfactory, so far as clearances are concerned, but there is no doubt in my mind that owing to the intense changes of temperature in any engine the aluminum pistons are apt to be eaten away in very little time. An aluminum



A Cast-Iron Piston Weighing 15 Oz. Which Wore Rapidly above the Wrist-Pin and Below the Bottom Groove Due to Insufficient Metal

piston after a 50-hr. test on a Liberty Twelve engine is shown. This is considerably corroded and is merely an example of the effect of continuously changing temperature or quality of mixture on an aluminum alloy. The lightest form of cast-iron piston that I have been able to develop to date is also shown, the weight being 15 o... and the diameter 3⅛ in. The surface above the wrist-pin and below the bottom groove was insufficient and the piston wore rapidly at that point.

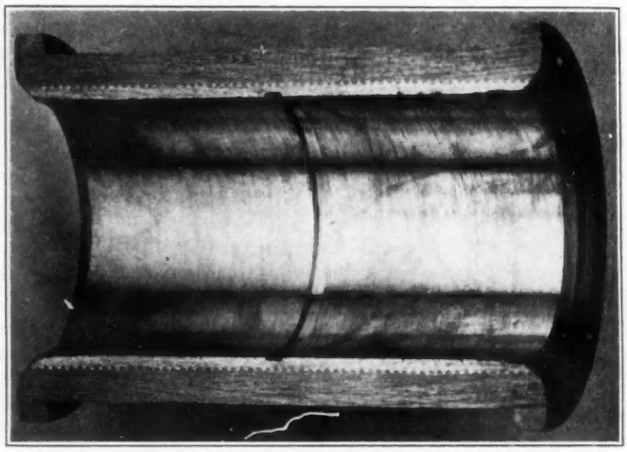
Before leaving the interesting subject of pistons, let me mention that in multiple-cylinder high-speed engines with relatively small bores and large superficial area of combustion chamber walls, it is highy important to prevent the water, which is ever present at combustion, and the gasoline, when an enriching carbureter device is used for starting in cold weather, from getting past the pistons into the crankcase, thereby causing stoppage of lubrication by the water becoming frozen, or corrosion of parts, such as ball bearings, distributor breaker-points, where this essential is designed into the engine, crank-pin journals and mainshaft bearings. This menace cannot be too seriously considered, and the only remedy is the accuracy of piston and cylinder fits and proper piston lubrication, all of which goes hand in hand with cast-iron pistons in cast-iron cylinders. The table of piston clearances given on page 331 will be of interest as bearing upon the above points.



Forced Lubrication System Used on a High-Speed Eight-Cylinder Passenger Car Engine

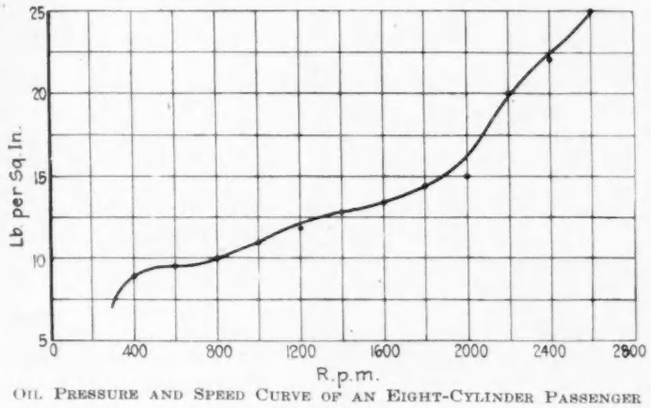
Necessity for Forced Lubrication

High speeds or continued speeds under high power cannot be maintained satisfactorily without the use of forced lubrication. One example which we had before us not so very long since was in connection with the Liberty engine, where an attempt had been made to feed the connecting-rod crank-pin end bearings by oil thrown from the main bearings. This proved entirely unsatisfactory after tests carried out by H. M. Crane of the Wright-Martin Aircraft Corporation, John Wilkinson of the H. H. Franklin Mfg. Co. and myself, and was abandoned by agreement with the Government engineers in favor of forced feed. It is very necessary that a large volume of oil should be pumped under pressure and not merely a small one, and there should always be reservoirs with separate leads to the bearings.



A Circular Groove in the Center of the Bearing Acts as a Reservoir for the Oil and Serves to Distribute It Around the Entire Circumference

The lubrication of Cadillac eight-cylinder engines is by oil under pressure. A supply of oil is carried in the oil-pan *A* and is drawn through the pipe *B* by the pump *C* and forced through the supply pipe *D* to the main bearings *E*, *F* and *G*. The connecting-rod bearings *H*, *I*, *K* and *L*, on the crankshaft, are lubricated by oil from the main bearings forced through holes drilled in the crankshaft. The pressure of the oil is regulated by an overflow valve or pressure regulator *M*, containing a valve under spring tension. When the pressure for which the valve is set is reached, it is forced open and the oil overflows past the valve. A small hole drilled in the regulator housing allows oil to by-pass the valve when it is seated. Oil flowing through the by-pass and forced past the valve is carried to the camshaft bearings and power pressure pump, in the gasoline system, through the pipe *R* above and parallel to the camshaft. The forward end of this pipe is fitted with two nozzles from which oil



Oil Pressure and Speed Curve of an Eight-Cylinder Passenger Car Engine

flows into the camshaft sprockets and to the chains through holes drilled in the camshaft sprockets. The cylinders are lubricated by oil thrown from the lower ends of the connecting-rods. There is one gage *O* located on the instrument-board and one indicator *P* in the lubricating system attached to the upper cover of the crankcase near the carbureter which shows the level of the oil in the oil-pan *A*.

One advantage of forced lubrication is the decrease in frictional losses. Tests made with varying oil pressures proved that the engine was quieter at the higher pressure; and the frictional horsepower was, with high oil pressure, only 60 per cent of that without pressure, and 72 per cent with medium pressure. We have carried out some very extensive tests on the Cadillac eight-cylinder engine at high speeds and have been able to maintain power for periods extending over 400 hr. at 4000 r.p.m. without adjusting the bearings at all. In addition to this we have been able to maintain maximum power at 3000 r.p.m. for 12 hr. without stopping, which I consider to be a triumph for forced lubrication.

Some years ago I carried out tests of cast-iron and aluminum 3¼-in. pistons having different clearances, with and without extra oil supply. Table 1 shows the results obtained.

Oil grooves in bearings should be conspicuous by their absence, so far as the ordinary kind of groove is concerned. The only type of groove which I would favor is a circular one around the center of the bearing, which is actually a reservoir and tends to have the oil right around the circumference of the bearing so that it can reach every part of same. A photograph of a bearing with the groove described is reproduced.

I consider that it is important that the oil pressure should be low when the engine is throttled and increase with the speed. I have found this to be very satisfactory, and it is incorporated in the Cadillac eight-cylinder engine. A curve plotted between oil pressure and revolutions per minute which is self explanatory is reproduced.

Ignition

The most important factor in high-speed ignition is the time necessary to energize the induction coil. To compensate for this, it is necessary to increase the flow of current or lower the resistance in the primary circuit, and in doing this there is excessive sparking at low speed, which oxidizes the contacts and increases the resistance, making it necessary to clean contacts at very short intervals varying from 1000 to 6000 miles. The duration of

TABLE 1

INFLUENCE OF AMOUNT OF LUBRICATION ON BRAKE HORSEPOWER DEVELOPED BY ENGINES

Cast-Iron Pistons without Extra Oil Supply

Speed, r.p.m., 300	600	800	1,000	1,200	1,400	1,600	1,800	2,000	2,200	2,400	2,500
Clearance, in.											
0.002	3.4	9.3	12.2	15.5	18.7	20.7	22.4	23.2	23.2	19.4	18.0	17.4
0.004	3.7	8.8	12.8	15.9	18.9	21.6	22.8	23.4	22.6	23.4	21.3	20.9
0.006	4.4	9.5	13.1	16.5	19.4	22.2	23.2	24.0	24.0	24.0	20.2	20.9
0.008	4.2	9.7	13.2	16.5	19.1	22.2	24.8	25.1	23.9	22.4	20.6	19.5

Aluminum Pistons without Extra Oil Supply

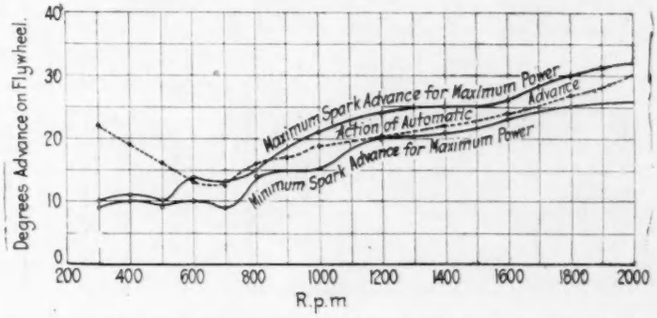
0.013	4.05	9.2	12.0	15.2	18.2	21.0	21.0	22.0	20.0	17.5	15.6	15.2
0.016	3.60	8.5	12.1	15.1	18.7	20.7	22.7	25.3	25.2	24.5	21.4	21.0

Cast-Iron Pistons with Extra Oil Supply

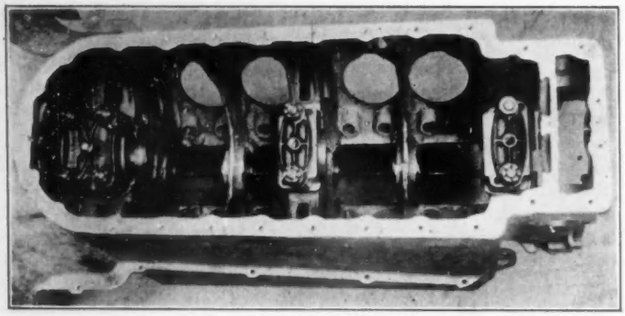
Speed, r.p.m., 300	600	800	1,000	1,200	1,400	1,600	1,800	2,000	2,200	2,400	2,500
Clearance, in.											
0.002	4.4	9.9	13.1	17.2	20.4	22.0	23.9	25.2	25.4	24.4	21.0	20.6
0.004	4.3	9.5	13.8	17.7	21.0	24.0	25.4	25.6	27.0	25.6	26.4	25.0
0.006	4.8	10.3	14.2	17.6	21.2	24.2	25.8	27.2	28.0	27.0	27.0	24.6
0.008	4.7	10.3	14.5	17.7	21.0	24.0	25.9	26.9	27.9	27.2	27.0	24.6

Aluminum Pistons with Extra Oil Supply

0.013	4.7	10.3	14.0	17.5	21.0	24.0	25.6	26.3	26.6	27.2	26.6	25.4
0.016	4.7	10.3	13.3	16.8	20.2	23.6	25.8	27.2	27.3	27.8	26.6	24.6


Degrees Advance on Flywheel
Maximum Spark Advance for Maximum Power
Action of Automatic Advance
Minimum Spark Advance for Maximum Power
R.p.m.

Curve of Degrees of Spark Advance on the Flywheel and the Speed of an Eight-Cylinder Passenger Car Engine



AN EXAMPLE OF THE USE OF REINFORCING RIBS TO STIFFEN THE CRANKCASE

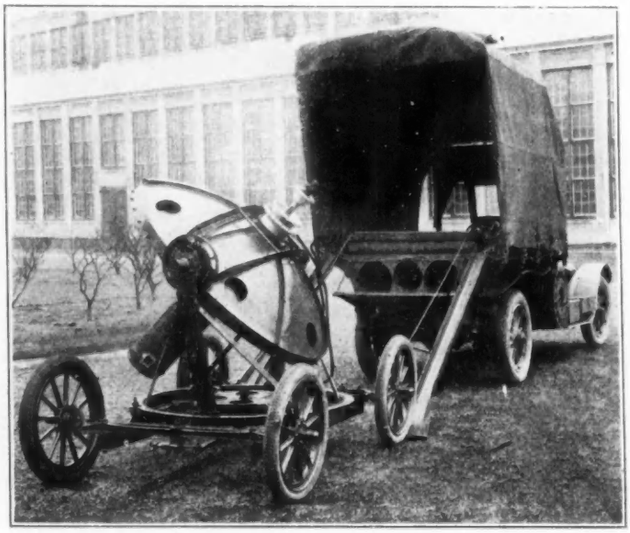
contact is very short due to the enormous number of sparks per second, and the oxidization mentioned makes one set of contacts unsatisfactory when compared with the life of a well designed multi-cylinder high-speed engine.

In view of this, my company started about the beginning of 1915 a continuous endurance run on three engines to see which part would wear out first. This run was planned to have a duration of 300 continuous hr., and we found that it was absolutely impossible to run more than 13 hr. at 2000 r.p.m. with the ordinary single arm breaker used on the first type of eight cylinder Cadillac engine. To overcome this serious objection, we built a distributor having two sets of contacts in parallel. Both closed and opened the primary circuit simultaneously, and, as each set carried half the current, the arcing at the contacts was reduced to a minimum. Due to the tremendous inertia at high speeds, the contacts when closing are inclined to chatter, thus causing the condenser to have a tendency to discharge and in turn producing arcing. This trouble is reduced to a minimum with two sets in parallel, as they do not chatter in synchronism, and the adjustment is not delicate. In initial adjustment one set opens late and all arcing takes place on this, causing it to waste away until it is in step with the other that opens first, so that they are synchronized automatically. This arrangement makes it possible to operate an engine at a higher speed than any other at present developed, because it increases the time to build up the induction coil by decreasing the resistance.

After this test we were able to increase the speed of our engine up to 4000 r.p.m., which means 266 sparks per sec., and after the installation of the two contacts in parallel, we were able to run a 400-hr. test without any ignition trouble, outside of occasional change of spark-plugs.

Two sets of contacts arranged to fire alternately have been used, but this makes it necessary to re-time or adjust contacts frequently, as half of the cylinders might be late in firing, which would cause a heated engine, and the other half of the cylinders early, which would cause premature or spark knocking. It would be impracticable to enlarge the contact area, because of the inertia at high speeds, as even the lightest contact arrangement is too heavy for high-speed work. If there is any eccentricity of cams and looseness of bearings with one set of contacts, these errors are very noticeable in the firing balance of the engine, but with the two sets of contacts 180 deg. apart the ignition is perfectly synchronized, a fact which is very noticeable indeed in the firing balance of the Cadillac eight-cylinder engine on block test.

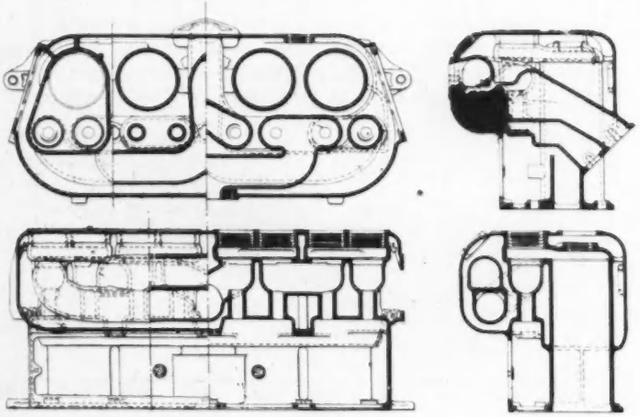
I believe that the ignition as applied to the eight-cylinder Cadillac engine has been brought to a higher state of perfection than any other ignition. My company gladly loaned this invention to the Government for use on the Liberty engine. Without this system, I believe that the Liberty engine would not have been so successful as it has been.



AN 11,000-LB. SEARCHLIGHT OUTFIT HAVING THE GENERATOR MOUNTED ON THE CHASSIS WITH THE SEARCHLIGHT ON A TRAILER THAT IS CARRIED ON THE CHASSIS WHEN NOT IN USE

Some curves showing degrees of spark advance on the flywheel relative to the number of revolutions per minute are shown and are self-explanatory.

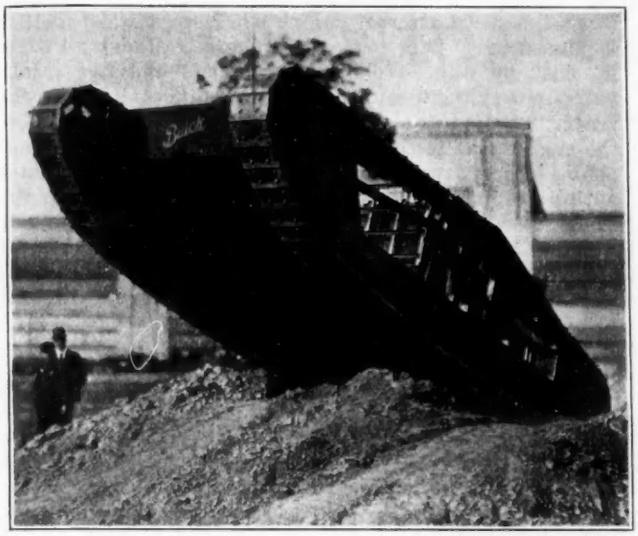
One can appreciate how great a factor is the inertia of the contacts, when it is stated that when running an eight-cylinder engine at 3000 r.p.m. the time between contacts is 0.0050 sec.; at 3550 r.p.m., 0.0042 sec., and at 3850 r.p.m., 0.0039 sec. With this in view it can readily be understood that very little variation can be allowed, so that we prescribe an error of only 1 deg. between the cylinders on our engine at all speeds.



DETAILS OF A CYLINDER BLOCK IN WHICH THE EXHAUST MANIFOLD IS CAST INTEGRAL WITH IT AND IS ENTIRELY SURROUNDED BY WATER EXCEPT ON THE TOP WHICH IS NEXT TO INTAKE MANIFOLD

GENERAL CONSTRUCTION

It is highly important that when engines are turning fast the maximum stiffness should be obtained in cylinders, connecting-rods and crankshafts. Above all, the crankcase should be extremely stiff and rigid to prevent



A British Tank Equipped with a Six-Cylinder Engine Undergoing a Test

weaving, bearings going out of line, etc., and thus causing vibration and other evils. In the Cadillac crankcase the method of employing reinforcing webs to give maximum rigidity is employed.

Carburetion is a difficult subject, because the quality of gasoline is rapidly becoming worse day by day. As the public becomes more critical of the performance of an automobile, the difficulties presented to the engineer become more acute. Undoubtedly, more heat must be applied to the manifolds to get proper and satisfactory carburetion, assuming, of course, that distribution is correct. We keep our manifold temperature around 170 deg. fahr. by means of thermostatic control. The thermostats are located in the water-pumps, causing valves to close or open, as the case may be, and thus prevent circulation of water through the radiator when the temperature is too low. This has been very satisfactory indeed, but with poor grades of gasoline a higher manifold temperature has to be maintained. Much has been said about exhaust heated manifolds, but this requires extensive study, as too much heat is as bad as too little, and it is possible to lose much power at the higher engine speeds unless great care is taken.

An interesting development is the design for a cylinder having the exhaust cast integrally with the cylinder block and completely surrounded by water except the wall next to the intake manifold, which is located above the exhaust manifold. The idea is that as the gases whirl the heavier molecules are thrown against the intake manifold walls, and, falling to the bottom wall, are immediately volatiized by the heat from the exhaust, the remainder of the gases being at normal water-jacket temperature. I designed this engine in 1915, and it was extremely successful, although never put into production on account of increased radiator capacity being necessary. This layout, it will be seen, incorporated the "hot spot" manifold.

Many other devices are in use, such as combined intake and exhaust manifolds, but many of these are, in my opinion, merely makeshifts to get rid of bad distribution, which, unfortunately, is so prevalent in many of our engines today.

The shuttered radiator also is a satisfactory layout, but requires considerable development owing to danger of shutters freezing, wind pressure causing shutters to remain either entirely open or closed, rattles, etc.

In the Cadillac four-cylinder 1914 type engine an electric heating element was used in the carbureter. This consisted of nichrome ribbon between mica sheets, attached to the upper surface of the diaphragm, that is, the plate which supports the venturi tube. The gasoline which condensed in the intake pipe and mixing-chamber dropped down on this diaphragm and was vaporized by the heater. In operation, current was put through the heater for a short time before starting, so that this diaphragm and the metal of the venturi tube were heated and any fuel on the diaphragm was vaporized.

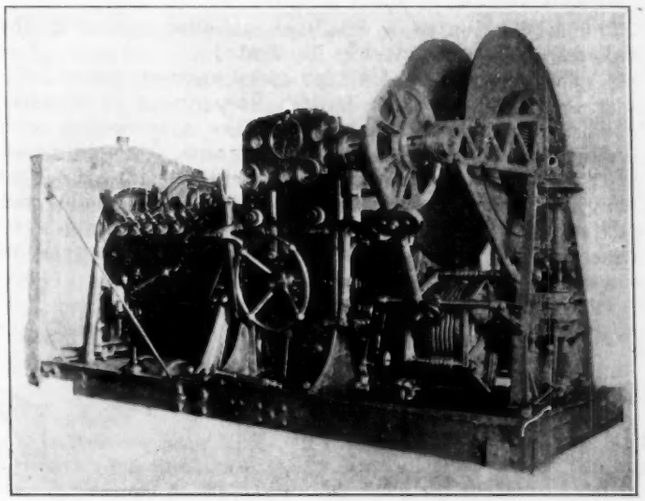
Weight of Engines

Since the advent of aircraft engines much has been learned regarding weight reduction. I am doubtful if many of the materials used in aircraft engines will ever be used in automobiles for commercial production, but we have an aluminum engine before us and there does not seem to be much doubt that in time we shall see many of these on the road and that possibly automobile engines will come down around 4 or 5 lb. per hp. We used to dream of 7 and 8 lb. with all accessories, and I am in great hopes of seeing good development in this line.

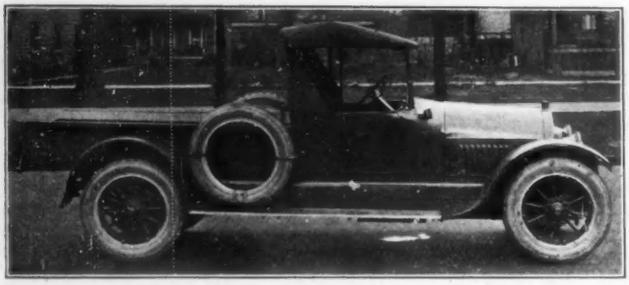
In 1909 I designed a high-speed four-cylinder engine weighing without the flywheel 5¼ lb. per b.hp. The 2½-liter Crossley engine weighed 4¾ lb., neglecting the flywheel, while the 3-liter Vauxhall in similar condition weighed 7¼ lb. per b.hp. and the Princè Henry Vauxhall, 5 lb. The Cadillac eight-cylinder engine, complete with the generator and without any flywheel, weighs 8 lb. per b.hp.

Use of High-Speed Engines

During the war the high-speed Cadillac eight-cylinder engine has been used extensively, and I have gathered together a few photographs illustrating the uses to which a high-speed engine has been put. One of these is a searchlight outfit developed by the General Electric Co. through its engineer, Henry S. Baldwin, working in conjunction with my company. A generator having sufficient capacity to operate a 60-in. searchlight for war purposes was mounted on the chassis. We believe that this is the largest lamp that has been produced, and the car has been thoroughly tested both in this country and for



An Application of a High-Speed Eight-Cylinder Engine to a Winch for a Captive Balloon



A Truck Chassis Equipped with an Eight-Cylinder Engine Which Carried a 2160-Lb. Load from Detroit to Washington at High Speed with a Fuel Consumption of 0.0912 Gal. per Mile

about 6 weeks in France prior to the signing of the armistice. We have records which show that it has never failed to meet any demands upon it as to power and structural features, and taking it all in all it is probably one of the most unique and successful devices that has been turned out. It weighed about 11,000 lb. less than the outfit that was previously used for the same purpose, and the vehicle had a speed of 45 to 50 as against a former speed of 15 to 20 miles per hr. When the searchlight outfit is not in use the trailer carrying it is pulled on top of the truck chassis.

Another example of the use of high-speed engines is in connection with tractors. The 2½-ton artillery tractor, into which was fitted the Cadillac eight-cylinder engine, was capable of traveling at a maximum speed of 21 miles per hr. This corresponds to an engine speed of 3500 r.p.m. The normal speed of the tractor is around 12 miles per hr., the engine speed on high gear then being 2000 r.p.m. The other gears at these revolutions gave speeds as follows: First speed, 3.86; second speed, 7 miles per hr. The gear ratios are as follows, the total reductions being between the engine and the track drive sprockets:

Direct or high speed—13.01 to 1
Intermediate or second speed—22.25 to 1
Low or first speed—40.50 to 1
Reverse speed—48.65 to 1

A tractor fitted with a Cadillac engine for the British Government is another application. Its space for carrying loads was forward of the radiator, instead of the load being pulled, as in the case in the 2½-ton Army tractor. The application of a Buick six-cylinder engine to the same chassis under test is illustrated.

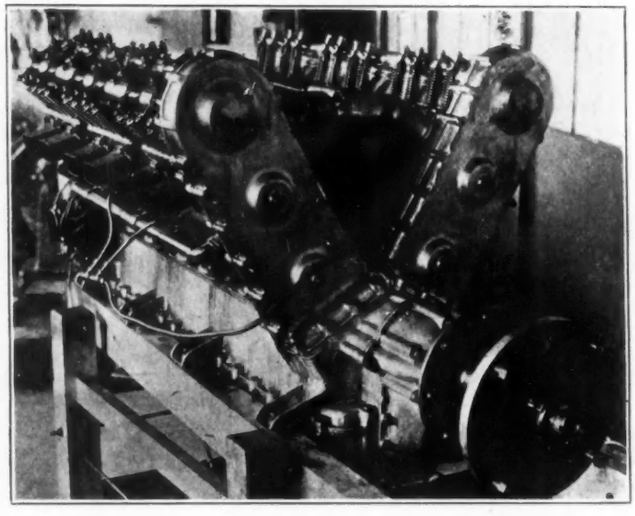
The installation of a high-speed eight-cylinder Cadillac engine used by the British Government in conjunction with a balloon winch, particulars in connection with which can be seen from the photograph, is another use.

A photograph of a truck chassis fitted with a Cadillac engine, which carried a load of 2160 lb., besides the driver and passenger, from Detroit to Washington very successfully indeed, is shown. The fuel consumption averaged 10.96 miles per gal. at high speed.

A high-speed aircraft engine which I designed in 1915 is illustrated. This engine had twelve cylinders, 4 3/16-in. bore by 6-in. stroke, two exhausts and two intake valves per cylinder and three carbureters mounted in the center. Owing to inability to obtain battery ignition, the engine was tested out with two twelve-cylinder magnetos. The engine had a dry crankcase, two oil pumps with a cooling system and geared-down propeller, as the engine was designed to pull 350 hp. at 2400 r.p.m. It weighed with cast-iron cylinders 1000 lb., which, of course, amounts to 3½ lb. per hp. This weight could have been very considerably reduced with steel cylinders.

The Discussion

R. K. Jack: I would like to have Mr. White's opinion as to the suitability of using the slipper type piston on an aero engine of large bore, say about 145 mm. We ran a test of over 50 hr., using aluminum pistons of this type, on a 500-hp. engine a few months ago, and at the end of this run the pistons were in splendid condition. The conventional type did not show up so well, and I should like to know if the advantages accruing from the use of the slipper type would be confined to engines of large bore.



A Twelve-Cylinder Aircraft Engine Having Two Intake and Two Exhaust Valves for Each Cylinder

Mr. White: I do not know exactly what type of piston Mr. Jack refers to when he mentions the slipper type. It may be that this slipper type is a piston where the surface is reduced on the sides very considerably. In other words, it is very like the old steam engine slipper guide. While this piston might be lighter, I think there would be great difficulty in keeping the piston round, especially for touring car work.

SIDE GUIDE & GRIPPER

Radiator Cooling Fans

By GEORGE W. HOYT[1] (*Member*)

MINNEAPOLIS SECTION PAPER *Illustrated with* DRAWING AND CHARTS

THE several units which go to make up the cooling system on tractors, trucks and passenger cars are the water-jacket, the pump, the radiator and the fan. There are important points in connection with water-jacket design, such as length and size of jacket, shape of compression chamber, wall thicknesses, etc., and special attention should be given to all of these to insure correct water capacity and also free flow of the water, at the same time making the necessary arrangements to prevent steam pockets.

A pump will throw just so much water. If the pump throws water into the radiator faster than the latter can handle it, the water will bank up through the tank into the cylinder and be held there until it heats. If the radiator is too large, steam pockets will form, hold the steam and cause overheating. If the outfit is designed properly the pump and the radiator will be of equal capacity. The pump must be designed to carry the water at such a speed that the radiator can be kept full at all times and still not have any hot water banked in the upper tank of the radiator, causing it to come back into the cylinders. It has been good practice in the past, as stated by Arthur Modine in his paper on Principles of Tractor Engine Cooling,[2] that for engines up to 50 hp. a good average amount of water to handle is 0.8 gal. per hp. per min. This works out very well. There is one type of cooling system, known as the thermosyphon cooling system, in which a water-pump is not used. The water capacity and the water passages are such as to allow free circulation of the water. It is also necessary to have a good water head in the radiator and above the cylinders, as the circulation depends entirely upon the hot water going to the highest point.

The radiator is of equal importance with all other units in connection with the cooling system. It has been proved that if we get an approximate frontal area of from 0.08 to 0.10 sq. ft. per hp., we can be certain of satisfactory results so far as the radiator is concerned. This area depends, of course, somewhat upon the type of core, which must have a good free air-flow, and also in part upon the thickness of the core. However, the specification given will apply for average conditions.

FANS

The fan, of course, plays an important part in the balance of a cooling system. There are many different installations on various makes of trucks, tractors and passenger cars throughout the country, but none the less there is always one way of doing a thing that is more nearly correct than any other. Among the engineers there is great uncertainty as to just what type, size and speed of fan should be used for different engines. This depends largely upon where the fan is to be used, on passenger car, truck, tractor or small lighting outfit. If used on a tractor, special attention should be given to keeping the fan bearings free from dust and grit by the use of good oil-tight construction, and this oil-tight feature should be adjustable. For the fans used on passenger cars or trucks, it is not so important to have this adjustable feature on the belt, although it is very good practice to get it if possible. Most engineers will agree that the fan is given about as little attention as any part of the engine, until trouble with heating begins. However, much improvement can be noted in the recent designs. It is found that by selecting a fan of proper diameter and speed to work in connection with other units, such as the radiator and pump, we get far better results. If this is not carefully looked into, we may have a fan running too slow or too fast, and the latter would cause fan noises. The fan may be too small also. These few points are merely mentioned to make clear the factors entering into the design of a cooling system.

It is best practice to use the largest fan that it is possible to get in back of the radiator, clearing all connections by at least ½ in. It should be installed so that the outside diameter of the fan will not overlap the upper or lower tank, and thus pull against a flat, closed surface. After the diameter of the fan has been determined the projected area or blade path must be studied, as this, in connection with the diameter and speed of the fan determines the number of cubic feet of air handled. It is good practice to make the width of projected area anywhere from 1½ up to 2¼ in., depending entirely upon the size of the engine to be cooled. It is sometimes impossible to get a fan of large diameter back of the radiator, and in this case the thing to do is to use a blade path as large as possible and still clear the fan belt by ⅜ in. We figure that this distance is entirely satisfactory for most commercial purposes, as the belt must be kept fairly tight or it will not drive the fan.

In case you wish to carry a certain volume of air, say that of an 18-in. fan running at 1800 r.p.m. with a 1½-in. width of projected area, and cannot get a fan of that size into the space back of the radiator, you can select a smaller fan with a larger projected area, giving the same volume of air and running at the same speed from the figures given on the curve charts for fans of different sizes and step down to that. In other words, it is possible to cut down the diameter of a fan, increase the size of the projected area and still carry the required volume of air at a given speed. Bear in mind that fans of large diameter and slow speed should be used where this is possible. That is just our way of avoiding a large-diameter fan, since all radiators will not accommodate them. You can cut down the size of a fan, increase the blade path, and still get good results.

SIZE OF FAN PULLEYS AND BELTS

After we have properly determined the diameter and width of a fan blade, the width and diameter of the fan pulley must be figured. For fans up to 16 and 18 in. diameter, we have found by experiment that a belt 1¼

[1]Chief engineer, Oakes Co., Indianapolis, Ind.
[2]Printed in THE JOURNAL, February, 1918.

SIDE GUIDE & GRIPPER

in. wide works very satisfactorily where there is no other unit driven by it but the fan. Where the generator is driven by the same belt, the latter must, of course, be wider and heavier. Fan diameters larger than those mentioned take belt widths up to 2½ in. While this is a large belt width, I mention it because we are furnishing it to some manufacturers.

The width of the belt depends upon whether the fan is driven from the flywheel or from a small driving pulley, and whether the speed is 2500 or 1600 r.p.m. Where the pulleys are small in diameter and run at fairly high speeds, a wide belt is needed to prevent slippage. Sometimes it is not possible to get a large degree of belt contact on the pulley. This condition calls for a wide belt, and after a car has been on the road for several months, subject to weather conditions, water, oil and heat, a little money spent on belt width which goes to keep the fan running and helps to keep the engine cool, is well expended. There is some choice between a crown-face and a flat-face pulley. It can be said that this depends somewhat upon the width of belt. If it is possible to use a wide belt, the flat pulley will work very well, and this is true of the belt widths thus far mentioned. However, the tests we have run show that a crown-face pulley is a little the better because it tends to keep the belt centered on the pulley, thereby getting the benefit of the full width of the belt. In cases where the driven and driving pulleys are not absolutely lined up with each other, the edge of the belt tends to ride on the flange of the pulley and decreases its efficiency at that point.

For the final decision on belt widths the material must be considered. Some materials stretch more than others and cause slippage. Wide belts help to overcome this trouble. No matter how efficient the fan may be, if the belt is not large enough to do away with all the slippage possible, the fan will be more or less of a failure for cooling purposes. If the belt is of proper width and the fan diameters are selected as has been suggested, the fan proposition is pretty well taken care of to this point.

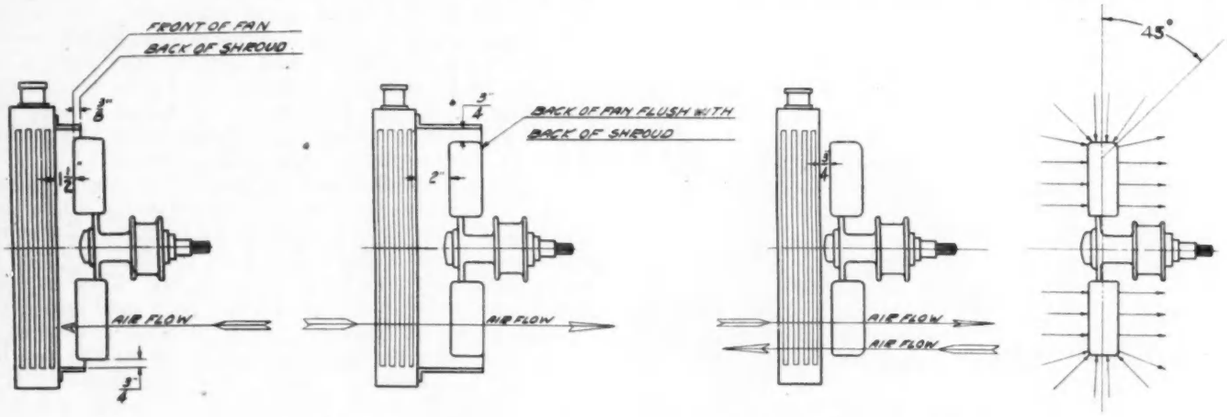
We have now practically determined the diameter and length of the fan, and it becomes necessary to settle the diameter of the fan pulley. Before this can be decided, it is necessary to know the approximate amount of air to be carried, and from past tests in the laboratory and the tests of radiator manufacturers we have found that for engines up to 50 hp. there should be an air velocity through the radiator of from 1500 to 1800 ft. per min. This depends, of course, upon the size of engine to be cooled. The smallest pulley used should not be less than 2½-in. diameter, where it is at all possible to install this and not interfere with any other part of the engine. Pulleys smaller than this, as I have said, are very likely to allow belt slippage and decrease fan speed considerably. The fan speed will, of course, vary with its size and the amount of air to be carried, but in general a large fan running at slow speed is more efficient.

The fan proposition then can be stated briefly. The fan pulley must be of such a diameter that in connection with the diameter and speed of the fan driving pulley the fan will rotate fast enough to carry the required volume of air, and the driving pulley must be large enough to allow a fan pulley diameter of at least 2½ in.

Fan Locations

Some manufacturers use a fan shroud on their car radiators; others do not. The location of the fan depends upon its use. Without a shroud, the fan should be placed with the front edge of the blades ¾ in. from the back of the radiator core. This is done so that there will be as little lost effort in drawing air through all sections of the radiator as when a fan is more than ¾ in. from the radiator. The fan will pull the air from the top and sides of the hood instead of through the corners of the radiator. This distance is also great enough to insure quiet operation and to allow for regular shop variations without interference with the radiator. The location just explained is satisfactory for blowing air as well as drawing air through the radiator, when not using a fan shroud.

When using a shroud and drawing air through the radiator, the front edge of the fan blades should be 2 in. away from the back of the radiator core, and the shroud should be designed so that its back edge will come flush with the back edge of the fan blades, with about 3 in. clearance between shroud and fan. While that clearance is shown on each side, it would be necessary for belt tension and tightening to make it possibly ¾ in. on one side and a little more on the other side, to permit adjustment of the belt. If a fan is set closer than 2 in. to the radiator when using a shroud, it becomes as noisy as when operating in a shallow pocket. The air has no chance to spread and take a free course through the fan. We find from tests that a fan placed with a 2-in. clearance will give very good results. It has more room in which to draw air through the corners of the



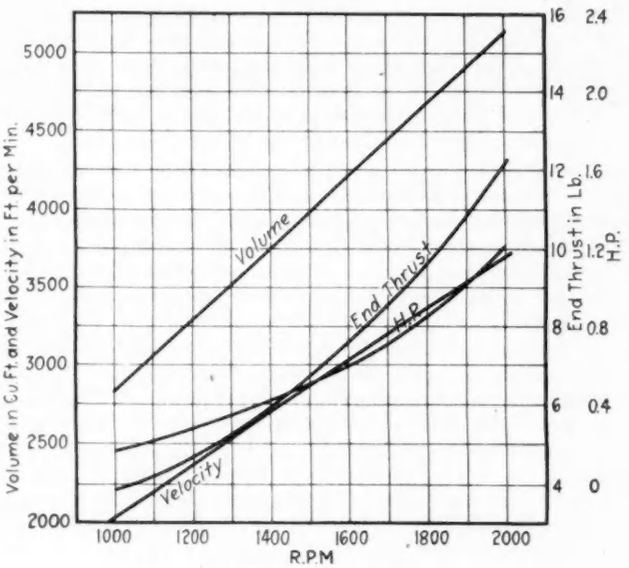
Various Locations of Cooling Fans with Relation to Radiator and Shroud

Blowing Air with Shroud | Drawing Air with Shroud | Blowing or Drawing Air, No Shroud | Curved Four-Blade Fan

radiator and is fairly quiet. The shroud, however, is not the sole reason for the increased efficiency.

There should be a number of louvers of proper size in the sides of the hood to permit the warm air to escape. Attention should be given also to the location of the floor-boards or anything that would tend to increase resistance against the fan. All these different pieces should be designed and placed in such a way as to allow the free flow and escape of warm air under the hood.

There is one other point to consider in the design of the fan shroud on a radiator. The shroud should be as



CURVES FOR A 16-IN. FAN

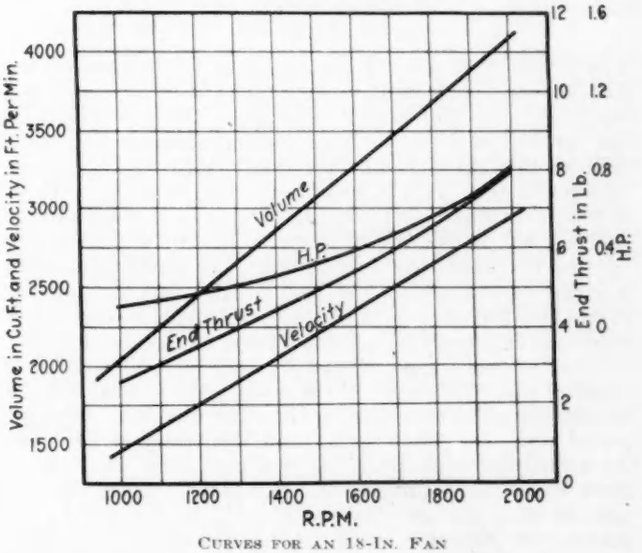
free as possible from angles, as these bank the air and hold it in. When a shroud overlaps the back of the fan blades, it will not allow the air to get away from the fan and even forces it back through the corners of the radiator. A fan is often placed with relation to the shroud so that half of the blade width will extend into the shroud and half back of the shroud. With this location air is drawn in all around the end of the blade, and one-half of the blade draws warm air from the engine under the hood and tends to keep this air circling around the end of the blade and decrease the amount of air handled.

There are other locations of a cooling fan such as placing it in front of the radiator when the radiator is in front of the engine. In this case the air should be blown through the radiator and at the same time carry away the hot air of the engine as if it were drawn through the radiator. With the fan in this position the hot air would be pulled through the radiator and have a tendency to warm the water instead of to cool it. There is, moreover, the objection to placing a fan in front of the radiator, that if both are not properly protected, the fan draws in dirt and weeds from the field and is likely to fill the radiator to such an extent as to decrease the chance of cooling the engine. When a fan is used in front of the radiator and a shroud is not employed, the fan is best located to force all the air possible through the radiator. If it is necessary to use a shroud with the fan in front of the radiator, we have found the position in which the shroud and the blade overlap satisfactory. This location has proved to be best, as the fan draws in air all around the end of the blade, being located with the front edge $\frac{3}{8}$ in. inside of the shroud to keep from spreading the air outside the shroud, and at the same time leave the largest part of the blade out in the open air, drawing in the maximum amount of air it can handle. By placing the fan in this case $1\frac{1}{2}$ in. back from the radiator, enough space is allowed between fan and radiator to spread the air so that it will pass through the corners of the radiator as well as the center. Bear in mind that we allow the fan to project outside of the shroud for the simple reason that it is not under the hood. If it were under the hood we would put it entirely inside and it would then draw the hot air as already explained. We want to place it far enough back to draw in the cool air.

For tractor purposes, I suggest the use of a fan shroud, since the maximum amount of cooling capacity is needed and this secures a gain of about 10 per cent, due to the fact that air can be drawn through the extreme corners as well as any other section of the radiator. If, however, a fan shroud is not well designed as to shape, length and diameter, it can do more harm than good.

In considering which way or in what direction air should flow through the radiator, it is well to bear in mind that we must avoid drawing hot air off the engine, as this will decrease efficiency. For a radiator placed beside the engine the fan location should be the same as when it is in front. There is one more location for a radiator, and that is back of the engine and at the dash. In most cases it is necessary to place the fan back of the radiator and drive it from the flywheel or propeller-shaft. The real objection to this location is that in most designs it backs up so close to the floor-boards that it is impossible to get maximum efficiency from the fan. However, the direction of air flow should be such that warm air will not pass through the radiator from the engine.

There is one point that I want to make clear with reference to the volume charts. Tests were made with a pitot tube and manometers, using gasoline in the latter.



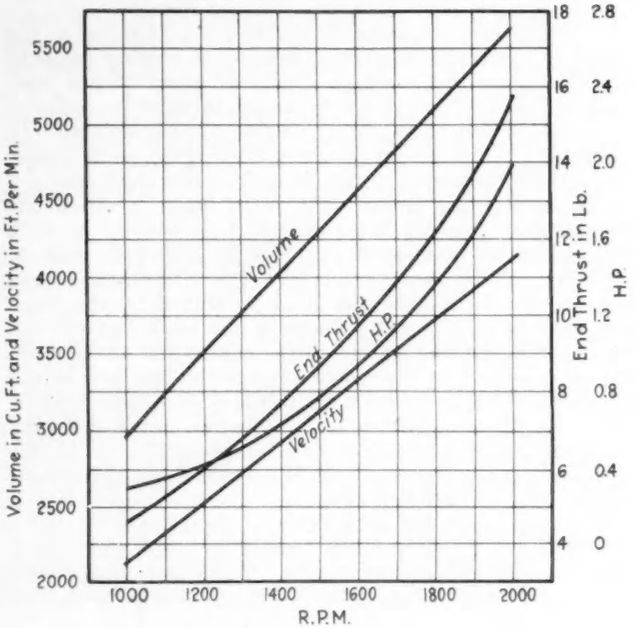
CURVES FOR AN 18-IN. FAN

Static pressures as well as the velocity pressures were taken into consideration in reading the height of the gasoline column. The fans were driven by a 5-hp. engine and were tested in an air tunnel 15 ft. long, tapered down to 16 in. in diameter. At the same time the volume test was made. We use this equipment to determine the end-thrust of the fan and also the horsepower consumed in

driving it. The pitot tube test is considered the most accurate for determining velocities of air handled by fans, and these should not in any case be compared with values secured by the use of the anemometer, as the latter are approximate only for velocities as low as 1000 to 1500 ft. per min. and these velocities can be obtained by the average-size fan at speeds as low as 800 to 1000 r.p.m.

Fan Bearings

The first thing to consider before selecting the type of bearing to be adopted is the load it will have to stand.



Curves for a 20-In. Fan

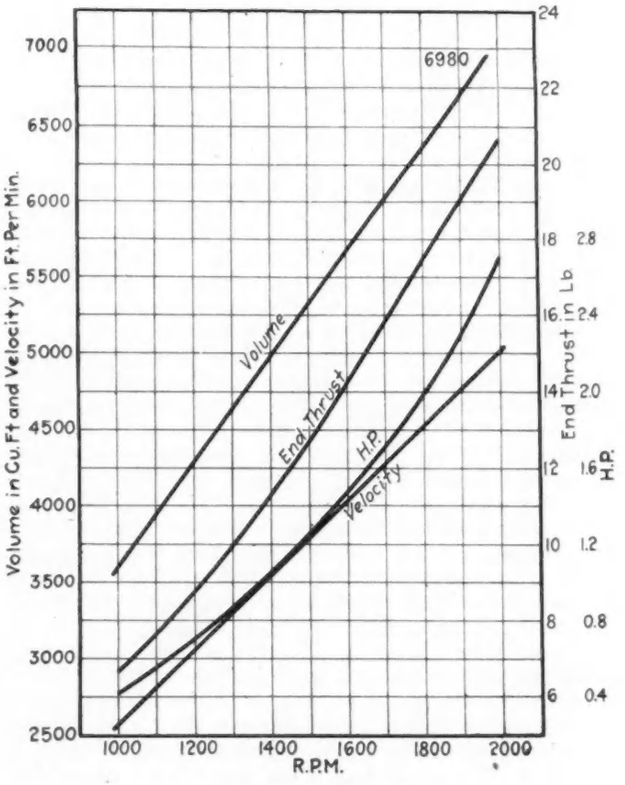
The radial load on a fan bearing is the weight of the hub, blades, spider and all parts that will revolve on these bearings, plus the weight caused by the tightening of the fan belt to secure a drive without slippage. In addition to this there is another load which is a very important factor. It is a well-known fact that the work of a fan is to draw or blow the air through the radiator and get rid of this air properly so that it will not bank up and decrease the fan efficiency. In doing this work a large percentage of the load on the fan bearing becomes end-thrust. In the past there seems to have been a certain difference of opinion among engineers as to the amount of end-thrust caused by carrying different volumes of air. There are three points which must always be considered in determining this, fan diameter, the projected area (or blade path) and the speed of the fan. An 18-in. fan with a 1½-in. projected area, running at 2000 r.p.m. will produce an end-thrust much less in amount than the same fan with a 2¼-in. projected area running at the same speed. A fan running in the open air unrestricted will produce a certain amount of end-thrust, but when placed back of a radiator, between it and the dash and under a hood, this thrust is increased about 25 per cent. The amount of increase depends of course upon the amount of restriction of the air. The air will flow through some radiators more easily than through others; some engine hoods have better air outlets than others; which tends to vary the thrust.

A straight roller bearing, if used with a hardened and ground outer sleeve and spindle, will make a very satisfactory bearing for taking care of the radial load, but some special arrangement must be made to take care of end-thrust, the amount of which is such that it should have a ball bearing. A 22-in. fan with 2¼-in. projected area running at 2000 r.p.m. and carrying a volume of air of 6890 cu. ft. per min., will produce an end-thrust of about 20 lb. carrying this through a 16-in. tunnel.

About one out of every ten people who own and drive cars ever oils the fans, but if a plain washer thrust-bearing does not get oil it soon becomes loose and noisy. A ball thrust-bearing of course wears out in time, but there is no doubt that there is less friction in it than in the plain bearing. Engineers who have had experience with end-thrust bearings will agree that the ball end-thrust makes much the higher grade construction. The amount of end-thrust can be found in the curves.

The proper size of annular ball bearing for fan purposes will give satisfactory results and carry both radial and end-thrust loads, but it must be kept properly oiled.

The cup and cone type bearing is by far the most popular, about 75 per cent of the fans used today being equipped with it, which is proof of its efficiency. It is adjustable for both radial load and end-thrust. Properly made and adjusted it will run longer under the abuse that a fan gets than any other type of fan bearing, with the possible exception of an annular one. These two bearings are very much alike, as far as carrying load is concerned, except that one is adjustable and the other is not. It is possible that the cup and cone bearing needs a rather delicate adjustment to work properly and be a life-long proposition, but this is true of any adjustable bearing. Plain washers must not be clamped too tightly or they



Curves for a 22-In. Fan

will score and bind; if they are too loose they will rattle; hence special attention should be given in both cases.

The essential for long-life fan bearings is to make the hub as tight as possible so that the oil can be kept in and the dust out. To accomplish this, the hub must be designed to hold a good amount of oil or grease and the felt washer retainers be adjustable. A felt washer that has no adjustment will in time wear large around the shaft and become oil-soaked to such an extent that it gets soft and worse than no washer at all. If we have an adjustment, the felt can be kept tight to the shaft and the oil kept out of the felt, thereby getting a much tighter fan hub. We put adjustable felt washer retainers on the differential carriers of a rear axle, or on front wheel and transmission bearings to keep the washers tight; and this is needed also on the fan hub, which, bear in mind, has the highest speed of any part of the engine.

Author's Conclusions

I hope I have made clear the points to which special attention should be given in laying out a cooling system, and the reasons for these. No one unit can do all the engine cooling; all units must be designed and adapted to each other. I suggest that manufacturers of motor vehicles cooperate with the accessory manufacturers to such an extent that the latter can help to solve mechanical difficulties, since there is no one particular fan or pump or radiator that will meet all the different conditions, and thereby give the maximum amount of efficiency.

The Discussion

A MEMBER:—Is there any particular advantage in making the contour of the fan an arc?

MR. HOYT:—We have made a number of fans with just a flat blade. To make this blade strong and free from vibration we had to put a rib or groove on it, which being on the air-driving side decreased the efficiency to a certain extent. We can get a much stronger and at the same time more efficient blade by making the curve, since we do not have to groove it. In the tests we made in our experimental work we found we got a stiffer blade and one that did not retard the flow of air.

A MEMBER:—What angle do you use?

MR. HOYT:—We have angles of 30 deg.; that is, the radius is 3 in. and the arc is on a 30-deg. angle.

A MEMBER:—What minimum clearance do you allow between the fan and the inside of the shroud where you have an eccentric for taking up the belt?

MR. HOYT:—It is good practice to allow for taking at least 1½ in. out of the belt length, and to do this the centers should be changed ¾ in. on each side of the belt.

CHAIRMAN H. C. BUFFINGTON:—What effect has the square corner of a shroud on the drawing in of the air?

MR. HOYT:—The corners do not make much difference. It is well to make the shroud as nearly square as possible so that the fan will be equally spaced in height as well as in width. The great point on the fan shroud is the angle from the radiator to the back of the shroud. I have shown this straight merely for simplicity.

CHAIRMAN BUFFINGTON:—What I had in mind was the possibility of creating a sort of eddy where the air would blow back through the radiator at the corners.

MR. HOYT:—You will not have that to any great extent if you place the back of the fan shroud flush with the back of the blades. It hits that angle of the shroud and returns. In my work I have tested this with some light material and I find it will pull in the center of the radiator and blow away at the corners.

A MEMBER:—I notice that in one case the air is drawn in from the outside of the fan blades. In tests I have made with fans I have always found the opposite to be true. I have blown smoke into the front of the fan and had it thrown away from the blades.

MR. HOYT:—The trouble was that you used pretty light material. There is so much air carried into and whirled around in the fan that it would be almost impossible to determine the flow of air definitely from your experiment. The test from which the curve was derived was made with an anemometer. The curved blade creates a vacuum in the back of the blade. It is a thing hard to explain but it can be shown nicely with the anemometer.

A MEMBER:—Is there not a critical speed for fans?

MR. HOYT:—We do not recommend fan speeds higher than 2000 r.p.m. with the engine traveling at the average speed. In passenger cars with engines that will run up as high as 2000, 2100 or 2200 r.p.m. on the road, the fan speed will be 3000 to 3500 r.p.m., but these conditions exist only at the highest speeds and do not last long enough to do harm. A fan will run much higher than an engine can force it, if consideration is given to the speed.

A MEMBER:—What would be the difference between an 18-in. fan with 1½-in. projected area and a 15-in. fan with 2-in. projected area?

MR. HOYT:—If the same volume of air is carried, there is not much difference in horsepower. I think the larger fan would take more horsepower. That particular point is shown on the charts.

A MEMBER:—When you increase the projected area, do you not also increase the width of the blade?

MR. HOYT:—That depends upon how far we go. With our spiders we can increase from 1½ to 1⅞ in. by using a 3 and 3 5/16 in. blade width. If we go above these dimensions we have to use a 4-in. blade. That is the width of the blade making 2¼-in. projection.

A MEMBER:—How many blades do you find necessary?

MR. HOYT:—Our best results have been secured with a four-blade fan. We can go as high as five blades and not have any great amount of trouble. Six or eight blades are too many; they chop up the air, and leave the space between the blades too small. We find that for production, efficiency and speed the four-blade fan is satisfactory. We can go to two blades, but here the speed has to be increased to such an extent that the bearings suffer.

MR. NELSON:—Suppose you curve the end of the blade a little on the farther corner, making it like a centrifugal fan; would it not have a tendency to push air out instead of drawing it in?

MR. HOYT:—It would make a difference, but I cannot say just what it would be, as I have not tried out that shape.

A. W. SCARRATT:—I have always believed that a fan is purely and simply a propeller, and the efficiency of it, therefore, the direct result of the thrust capacity it is able to develop. In every type of propeller now considered efficient the spiral form of blade is used. Why does that type of blade not succeed in ordinary fan design?

MR. HOYT:—The propeller type of blade is a good proposition, and I know of at least two firms that are using it for new fans. It requires an elaborate set of dies, which adds to the initial cost, and is somewhat heavier, but it is as efficient as the other type of fan. The curved type of blade gives a good stiff fan, which was our reason for using it.

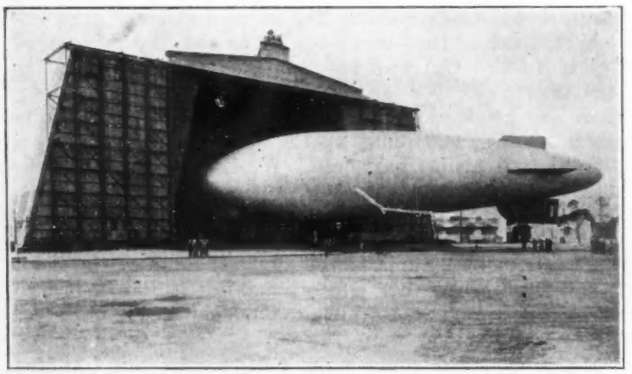
Naval Airships

By Commander J. C. Hunsaker[1] (*Non-Member*)

Aeronautic Meeting Address *Illustrated with* Photographs and Drawings

It has been very gratifying to all of us, especially to our own builders and manufacturers, to learn by an inspection of what the French, Italians, English and Germans have done, that we are superior to any of them in workmanship and care in the handling of materials. In design we are certainly on a par. In some types we are superior to them; in others we are not. It is a fair average. Glenn Curtiss is the father of the flying-boat, and both he and we are glad to know that the flying-boat is still an American institution.

In connection with lighter-than-air craft, we have always lagged behind and are still behind, but we made a late start. For example, in the care of free balloons and the early dirigibles, the experimental work and the pioneering were all confined to France. The French two generations ago had worked out the complete theory of design and operation for these types. They knew all about them before there were gasoline engines to put into the airships to make flight at all useful. The Germans started with airship work about 1895; the Italians somewhat later; the English, I think, made no serious effort until about 1911 and 1912. The United States began in earnest in 1917. Following the example of our English friends who have quite caught up from the time they have been at it, we ought to be able to catch up very shortly, if Congress will vote the necessary funds.



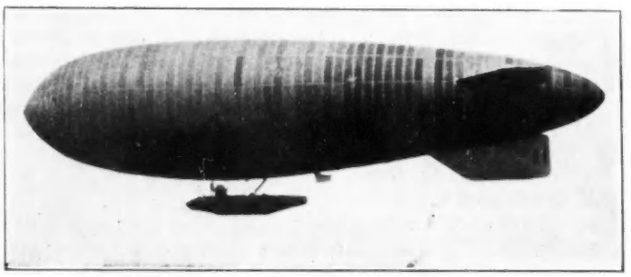
Navy Training Airship Entering Hangar

Beginning of Airship Construction

The first serious work with airships in the United States was done in 1917, when the Navy Department arranged for the construction of sixteen small ships. They have been described as "blimps." I would like to correct one rather general impression that these ships were based on a foreign type. They were not, but were designed before the United States had gone into the war from a picture on the back of a postcard that was smuggled out of England, and from an account by a returned traveler who had seen something in England that he tried to describe. We had the information that the English were working on a certain small airship for a submarine scout and that the type was useful. We then started with the same general problem, and as very frequently happens, we came out with about the same result.

As I have said, we built sixteen of these small ships. The principal characteristics of the type are as follows:

Volume, cu. ft.	84,000
Length (overall), ft.	164
Type of engine	Curtiss
Size of engine, hp.	100
Speed, miles per hr.	45
Range at full speed, miles	500



The Navy Airship C1 in Flight

They are not remarkable for any great performance, but they have trained 150 pilots for us in the time we have had them working, and have done about 4000 hr. of patrolling, covering 140,000 miles.

Thus far there have been no lives lost as a result of accidents to these ships, although almost everything that could has happened to them. I think that is a very good record. We claim, of course, that the principal reason for the fine showing is that the ships were well built to begin with.

These ships have been doing regular submarine patrol work along Atlantic coastal waters throughout our period in the war, and have acted as convoys for whole fleets of merchant ships; they have really been useful for that limited function. They cannot go very far to sea because they have only one engine. We had one case where a few lads in one of them got caught out at sea and in a helpless condition drifted for two or three days and came down at Halifax. Their being saved was more good luck than good management, so we decided that we wanted two engines, and have brought out our second type with twin Hispano-Suiza engines. This is nearly twice the size of the first model and the speed was pushed up above 60 miles an hr., the radius being about the same. The ships with the twin engines are fairly new, but the first one of the series has flown from Akron to Washington, then to Rockaway, and now it has gone down from Rockaway to Key West. The longest flight was, I think,

[1] Bureau of Construction and Repair, Navy Department, Washington, D. C.

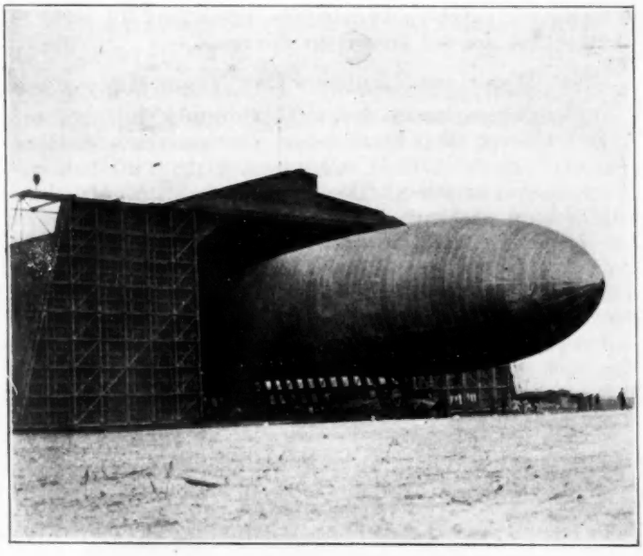
30 hr. We are building about fifteen of them, and hope to make small changes from time to time to improve the general type.

For 1919 we shall bring out a new ship of an improved type, a little larger. It is naval tradition that the Bureau of Construction and Repair brings out a new "spring style" every year. We have not yet shown our style for this year, but shall do so shortly. I have been talking about last year's spring style.

These non-rigid airships can be built pretty rapidly, and as we know from our own experience, they are fairly safe. They are used principally for coast patrol and convoy work. Their duties are supplemental to the rapid and intensive surveillance of coastal waters by seaplanes.

We always want to be sure that we do not get into any argument with our heavier-than-air friends. There should be no argument. I once heard two men argue as to whether the mountains are better than the seashore. You cannot settle such questions by argument, nor can you settle by argument whether the seaplane is better than the dirigible. It all depends upon what you want them for.

The seaplanes watch the area within 100 miles of the coast and zig-zag back and forth over assigned sectors during daylight. The small airships proceed further out to sea beyond the range of seaplane patrols, to watch for submarines and enemy mine fields, but principally to accompany convoys of merchantmen. An airship can loaf along for a day or two with the convoy and not leave it to return to port until it is well out in the open sea and comparatively safe. This function of convoying ships out from our coastal waters is pretty well accomplished

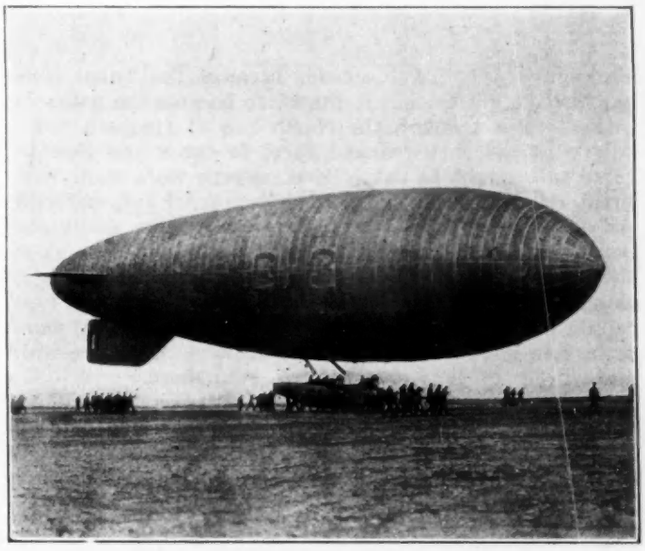


NAVY AIRSHIP C3 LEAVING HANGER

by our present types, but of course we shall keep on improving them. However, the amount of improvement that we can get is not very great. When we come to consider the fleet requirements for a strategic scout, we must have an airship with an endurance in the thousands rather than hundreds of miles. We have then got to think of the German Zeppelin. The Germans have developed just such a weapon, have taught us how it should be used and how it ought not to be used, and have very obligingly presented specimens of their work to the Allies from time to time, so that there are no longer any secrets about it.

THE ZEPPELIN

The black paint on the belly is put there for night work, so that the ship will not shine in the beams of a searchlight. The top of the ship is left white, so that some light will come through the outer cover and illuminate the interior where men may be working. That particular type of ship is intermediate between those with which the Germans started the war and those with which they finished. It is about 2,000,000 ft. and plenty large enough to cross the Atlantic and get back again, in good weather.

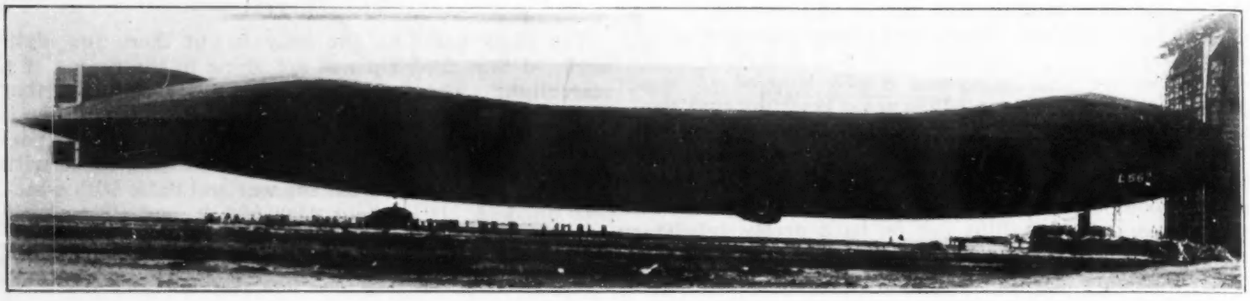


NAVY AIRSHIP C3 ON THE FLYING FIELD

The Germans had a considerable fleet of Zeppelins available at all times during the war, in spite of such losses as they are known to have suffered from attempting to bomb towns in England. Admiral Jellicoe has just written a book in which he discusses his handling of the Grand Fleet during the first 2 yr. of the war, and in it he states very clearly that the Germans enjoyed a distinct advantage over him, due to their possession of Zeppelin scouts. He mentioned one specific instance when a cruiser force was sent out from Harwich to make a sweep down the North Sea and was embarrassed by being tagged by a Zeppelin throughout the entire period of daylight. The commodore of the cruiser force could merely report that he found no German ships at large on the North Sea and that he was watched by this Zeppelin all day.

On another occasion the entire Grand Fleet was out with all forces, destroyers and light cruisers, battle cruisers, battleships, etc., and made a wide sweep down the whole length of the North Sea. On that day the Germans had ten Zeppelins out, which stretched in a line across the North Sea. The Fleet, of course, found no Germans on the water.

This matter of sweeping the North Sea was the principal occupation of the Grand Fleet. In addition to having to restrain the German High Seas Fleet, the British had to maintain an effective blockade, to deny access to the Atlantic steamer lanes to German commerce raiders, and to protect the British coast from raids by German cruisers. All this was done in spite of German submarines. It was not possible for the British to maintain



AN EARLY TYPE OF ZEPPELIN

Farragut's type of blockade, because the submarines would have got them. It therefore became the policy to make sweeps through the North Sea at frequent intervals with the entire Grand Fleet to catch any German force that might be out. These sweeps were made with great risk and wear-and-tear on personnel and material. All of this might have been done much more easily and more profitably if the British had had rigid airships of the Zeppelin type. During the first 2 yr. of the war, I think, no substantial number of Germans were ever caught out, except at Dogger Bank, and then they more or less all got back. Then came Jutland, and more Germans got back than should have, even there.

Considering the problem of the North Sea, the English have had some years to study that and have now learned their lesson and are proceeding with the greatest energy to develop an air fleet of all types, including the very largest rigid airships, as part of the fleet. They began at the beginning of the war, had many disappointments and considerable success, and, assisted by the Germans' example, as they have been, are now building ships that are the equal of the Germans' in performance.

The United States Navy has not yet started on this kind of building, but when we do our engineers and manufacturers will have the benefit of all this German and English experience, and I, for one, have no doubt what the result will be.

Zeppelin L64 is about 2,000,000 cu. ft., which means that its lift is 61 tons. The useful part of this is 33 tons, that is, over 50 per cent. These ships will carry over 55 per cent and the larger types 60 per cent of their total capacity as useful load. The speed of the last ship was 77 miles, which may, I think, be increased to something above 80 miles by improvement in the powerplant.

We have learned something interesting about German engines. We have thought all along there was mystery about the power the Germans were getting, and it has now come out that they were rating some of their engines at 3000-m. altitude. So you see that they were not getting something for nothing.

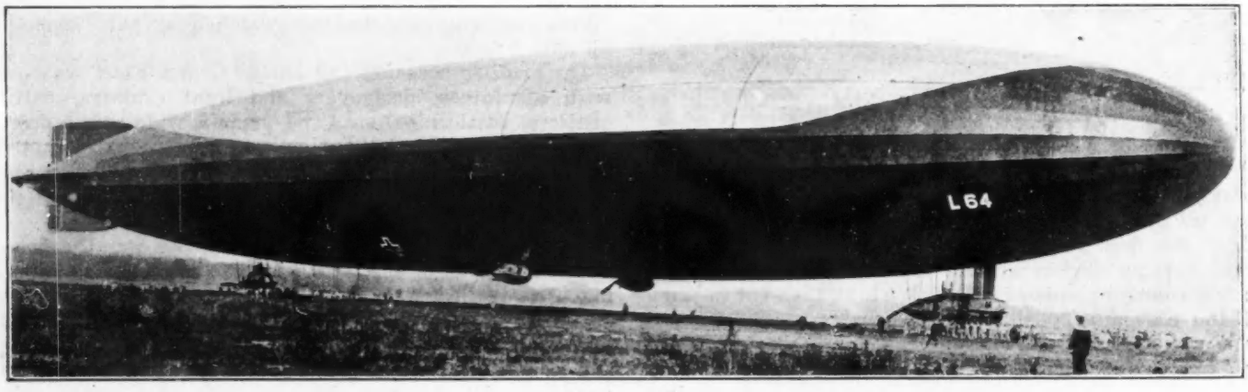
The diagram shows about where the United States stands. The little ship at the bottom is our big nonrigid airship that we talk about so proudly, and L-33, the middle one, is the German ship of 1916; the top one, L-70, is the German ship of 1918. It seems to be up to us to take another step.

The tracks that are drawn on the map of the North Sea indicate the routine patrols of the Zeppelin airships up to the coast of Norway and back again, and out beyond the Dogger Bank and back. These patrol lines are watching the movements of British ships approaching German waters. In addition to all this there were extraordinary patrols and bombing raids, and all sorts of things that are not shown on the map.

WHAT THE GERMANS CAN TEACH US

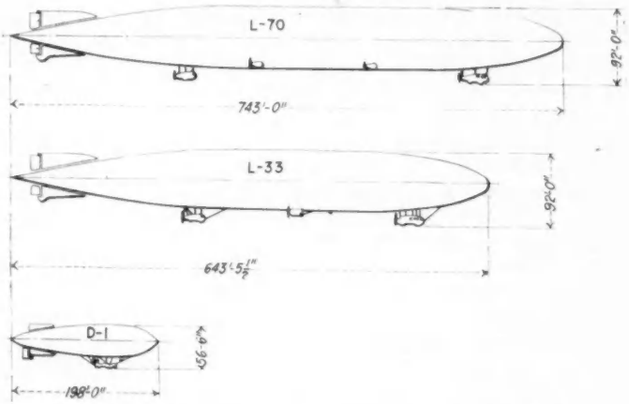
We can learn much from the Germans, and we will have to accept their competence in engineering matters, and even more in their organization than in their engineering. There is no time for me to talk now about the engineering problems in the design and development of the Zeppelin, but it is a very beautiful job, and it has been worked out logically and thoroughly. The designer almost speaks through it; you can see why he altered the construction from year to year.

The Germans concentrated all of the modern and working part of the entire Zeppelin fleet at three stations: Witmundshaven, Nordholtz and Alhorn. They had an-



A RECENT ZEPPELIN HAVING A 61-TON LIFT, 33 OF WHICH IS AVAILABLE FOR LOAD CARRYING

other station up at Tondern, but neglected to protect it properly with airplanes. The result was that a British man-of-war came in, launched some seaplanes with bombs and blew it up. To protect the three remaining stations from raids such as occurred at Tondern, they had the airship patrols which covered the North Sea. These gave them warning many hours in advance that naval forces were approaching. Behind the wavy line is the seaplane patrol. The seaplane stations were placed on the islands of Heligoland, Borkum and Nordholtz. Those stations maintained modern seaplanes of both patrol and fighting types, and the area inside of the jagged line was under constant scrutiny in the daytime. In addition to that, fighting seaplanes with machine guns, two ahead and one behind, were always ready to take the air on instant notice. These were lined up in the hangars

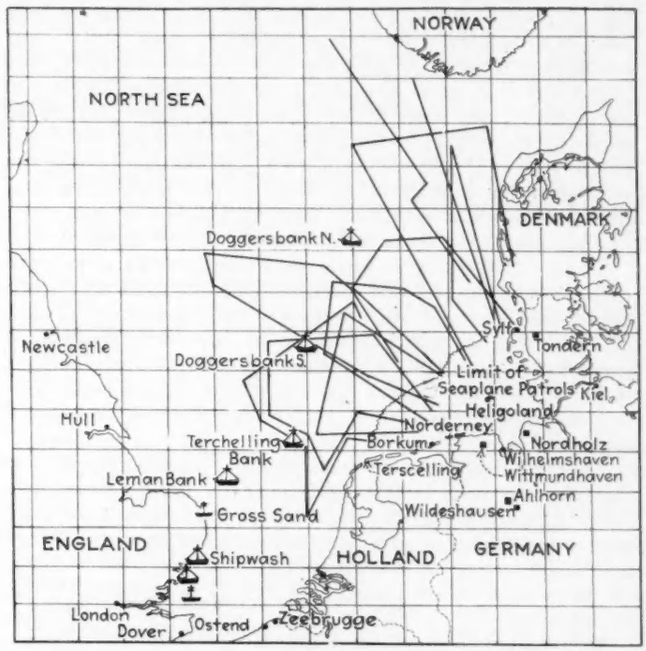


RELATIVE SIZE OF GERMAN AND AMERICAN AIRSHIPS

ready for immediate use. However, the Allies never attempted to make a raid on the German naval bases. It might have been very embarrassing for the English to make a long flight across the North Sea and then run into a hornet's nest of fighting planes. These planes were kept in steamheated hangars, fully warmed up. It was a lesson to me that steam heat was a military factor in airplane design. At one station there were ninety-eight new planes lined up, ready to start out.

In addition to this seaplane protection, the patrol and the fighters at each of the Zeppelin stations, was a squadron of land planes, in command of an army officer detailed to the naval air station. These planes were ordinary single-seater fighters, kept ready to take the air on receipt of an alarm from the seaplane stations.

On the matter of Zeppelin vulnerability, we were able to get certain statistics which appear to show that the Germans have lost about 50 per cent of their ships by fire, started either by accident or as the result of explosive bullets. Taking the same chances with the weather as the Germans, if we can substitute a non-inflammable gas, such as helium, for hydrogen, we should save 50 per cent of their losses. We ought to save all



ROUTINE AIRSHIP AND SEAPLANE PATROLS MAINTAINED BY GERMANY IN THE WAR

the fire losses. The United States is in a commanding position, having the only known available supply of helium. We should forge ahead and make use of this asset by building ships of the Zeppelin type to be filled with helium. Learning to operate will be much cheaper for us, since we shall not burn up the first few ships. The production of helium is an assured success, and if we can lift and float our fine constructive work with helium, I think the country will be well satisfied with the record we shall make.

INVENTORS

NATURE generally ordains that if a man be highly developed in one particular, he shall be inadequately developed in some other, and the form this law of compensation takes in the inventor is that his ingenuity and pertinacity are developed at the expense of his commercial ability. He will spend his last penny and his every moment on perfecting his model, when common business sense would show him that he ought to devote his time and money principally to his ordinary work, and treat his invention as a side line to be financed out of "excess profits." Perhaps one of the best illustrations of this point is a negative one—the frequency with which an inferior invention commands a commercial success, simply because the low-grade ingenuity of the patentee is coupled with comparatively high-grade business ability.

—Douglas Leechman.

Engine Performance

By H. L. Horning[1] (*Member*)

Chicago Meeting Paper *Illustrated with* Chart

I HAVE had a very striking illustration recently of the losses that occur in engines from the time they are conceived in the engineer's mind until they actually commence to plow the soil. I have sketched here a typical case of a 330-cu. in. engine that I happen to know about, and have drawn it under different conditions so as to show what is lost, and also to trace and point out the problems of the different men who are interested, the engineer, the customer, and the service department. I have left out the manufacturing department which often in the shop takes mean advantage of the engineer.

If this 330-cu. in. engine were as good as a Liberty airplane engine, it could deliver 57 hp. at 1000 r.p.m. In actual test the best we can get in the laboratory is 41.5 hp., and that is with everything in fine condition. That represents about 100 lb. mean effective pressure, which is about the best we can get out of an engine with cast-iron cylinders and all the hindrances common to tractor engines.

The next figure is the best possible horsepower that a manufacturer can hope to get from his engine when it is ready to ship; 33 hp. is about the average when an engine goes out, 29 hp. is not uncommon with gasoline, 23 is a common output with kerosene, 21 with bad piston rings, 19 with bad spark-plugs and 9.5 is available at the drawbar.

This diagram shows at a glance the immense amount of work the engineer, the manufacturer and everyone along the line still has to do. From the 57 to the 23 hp. or the common output with kerosene, which is not good, is the province of the engineer; within that lies the great engineering problem of the future. I know that already a great many experiments are being carried out to improve the compression at which engines can run on kerosene; the common tendency at the present time is to drop the compression to use the available fuels with their heavier constituents.

The problem from the 19 to the 9.5 hp. is the tractor manufacturer's. It may hurt the feelings of some of them for me to use these figures, for a few can easily show 13 instead of 9 hp., but it is not uncommon to get down to the lower figure. As you should have 10 b.hp. for every plow to be used, you realize what a difficult situation this is. What we really ought to have is an engine actually delivering 33 hp. all the time. Notwithstanding the many efforts that have been and are still being made by engineers to burn kerosene, it is my opinion, after years of work, that kerosene tractors are bought by the farmer to offset the possible robbery of high prices on the part of the oil interests. After they get their kerosene tractor they burn gasoline. I do not blame them after noticing the performances indicated on the diagram. It is not uncommon to drop from the 33 to 23 or even 10 hp. in the attempt to burn kerosene. It is my opinion, more from an engineering than from the user's point of view, that the user would be better off if he burned gasoline and kept the extra horsepower continually available.

With respect to the question of fuel, we are hearing and I presume that as the years go by we shall hear of many new fuels. But there is a limit to all this. Engineers must come to the realization that the question is not one of producing an engine for a particular fuel; they must produce an engine for the fuels that are available on the market. The fuel we are to get in the future is not the fuel that oil men will want to make; it is the fuel they will really have to make, and it is an open question whether there will be enough to go around. That is the governing factor.

Another problem is the marketing conditions. One of the most satisfactory things about the present status in the gasoline industry is the fact that one can get gasoline almost anywhere. To build up the organization that provides our present distribution, the Standard Oil and the other oil companies have worked for years and put in millions of dollars. They have to keep large reserves—$50,000,000 each sometimes—to meet the sudden demands for capital which occur when new fields are opened. It is capital, therefore, in the form of supply stations and organization for the distribution of fuel that will largely govern the types of fuel we are to have. That confines the engineer's problem to the task of building an engine that will burn any fuel, or fuel with a wide range of boiling points.

Using Different Fuels

I was greatly pleased yesterday to have a tractor manufacturer describe to me a heavy-fuel device which he had worked up. By turning a lever he could vary the amount of heat applied to the incoming charge. On the lever was an indicator marked Gasoline, Distillate and Kerosene. It was very simple and appealed to me strongly. The tractor and possibly the truck of the future could be equipped with just such a device. Then when kerosene is needed all the driver will have to do is to turn the little knob marked Kerosene; if he wants to burn distillate, such as is found in California, which I presume will be available more and more in the East as we learn to burn it well, he will turn it on. When he must make use of high-priced gasoline he will have it at hand. That seems to me to be an important step forward. We must realize that we have got to deliver power irrespective of the fuel, a very hard condition to put upon engineers under the circumstances.

In the summer of 1915, during the last S. A. E. cruise we made up the Lakes from Detroit, I had a very pleasant talk with President Kettering on the possible devices that could be worked out for catching the small variations in pressure inside of cylinders, and from that day to this Mr. Kettering has made an intense study of this problem. We have also done some work of this kind in our factory. It was through the suggestion and help of Mr. Kettering that we were able to produce a manograph which will allow us to spread the explosion curves out and produce a photograph in which 1 in. represents 0.001 sec.

It is fascinating to sit in the dark and watch the play of the curves as we burn kerosene, then inject water, and later vary the fuel to gasoline. There is a wealth of knowl-

[1] General manager and secretary, Waukesha Motor Co., Waukesha, Wis.

edge to be gained here which few engineers perhaps realize. If the engineer will stop long enough to adjust the carbureter and watch the various changes and curves, he will learn more, probably, than he could in years of field experience.

One of the interesting things we have learned is that the heavy-fuel knock which we all call "preignition," is really not preignition but after-ignition; it comes about 20 deg. after upper dead center and is so sudden that the pressure rises to 900 lb. per sq. in. As a matter of fact, I have seen the pressure go up to 1300 lb. per sq. in. The light beam moved so fast that the photographic film failed to catch it. Those are real explosions. They take practically no time, so far as I can measure about 0.0002 sec., to run up from 150 or 200 to 1300 lb. The heat dissipation is very rapid and the pressure drops down to the previous point in the same short interval. You get several such explosions one after another, showing that the cylinder is not doing a good job; the fuel differs so much from the lower range up to the higher that we cannot produce conditions in the cylinder which will permit uniform and practical burning.

All this is interesting from the fact that the higher the atomic weight of the fuel and the heavier the kerosene, the more prone it is to break down under pressure. That is the law of explosives. If you want to have just a little night scene, light some powder on a table; the powder will blow up, but very mildly. Put a plate over it and you will have a little fun. Put a cast-iron casing around it and you will have to get behind the building. Put it in a chrome-nickel steel retainer and there will be music by the entire orchestra.

The pressure half of the compression and the first part of the burning of the fuel run the pressure in the cylinder up so that the unburned part of the fuel, that which has not yet ignited is under very high compression and detonates. This has proved of practical interest, for if we are to burn kerosene and the heavier fuels in our present form of gasoline engine, we shall have to design a different type of combustion chamber to prevent these high pressures from getting to that part of the fuel which has not been burned. The ingenuity of some of the best engineers in Europe is now being applied to the solution of this problem, and I have no doubt that there will soon be marked advances along that line. It seems probable that one of the ways in which we can burn the heavier fuels will be by holding this terrific explosion wave or pressure back until we can feed the flame out gradually into the other part of the charge.

I hope that nobody will ask me anything more about this particular phase of combustion because I have told you all I know. I am very glad to have advanced thus far. I have made some experiments in the laboratory which give reason for hope. I met Mr. Stiger in the lobby of the Congress Hotel this morning, and being a gasoline carbureter man, he said, "There is nothing in this kerosene movement; there is nothing to be gained from it." That may be the truth and a solution of the difficulty. As soon as we get a serious demand for gasoline the refiners may loosen up and give us more and more gasoline out of the distillates and the heavier fuels, but it seems to me that the future will impose a very interesting problem upon our engineers. There will be no need of the refiners going to the trouble of breaking up the heavier fuels by processes already so successful if, by ingenuity and good understanding of thermodynamics, we can burn them directly in the engine. It would be a great mistake to spend money on fuel that could be saved.

In closing my remarks, I want to call your attention as engineers to something that I see nearly every day, either in our company or in others. The S. A. E. has among its members some very good engineers. History has been made by the work of these engineers and they are eminently capable of producing devices for the gasoline engine that are absolutely efficient. But their punch does not always get through to the purchaser. Somewhere in between it is lost. First, they produce a beautiful design and the factory changes the dimensions and off goes 10 per cent. Then the superintendent comes along and takes 10 per cent more. The chief inspector objects to fine dimensions and 10 per cent more is gone.

The engine is shipped out to the user. It is a new, raw engine and the man who has bought it has perhaps never run an engine before. It takes 3 or 4 months and sometimes a year for it to get down to smooth running. The first month has all the grief in the world in it, but if you can get the owner through the first year, he will not trade his engine for any other.

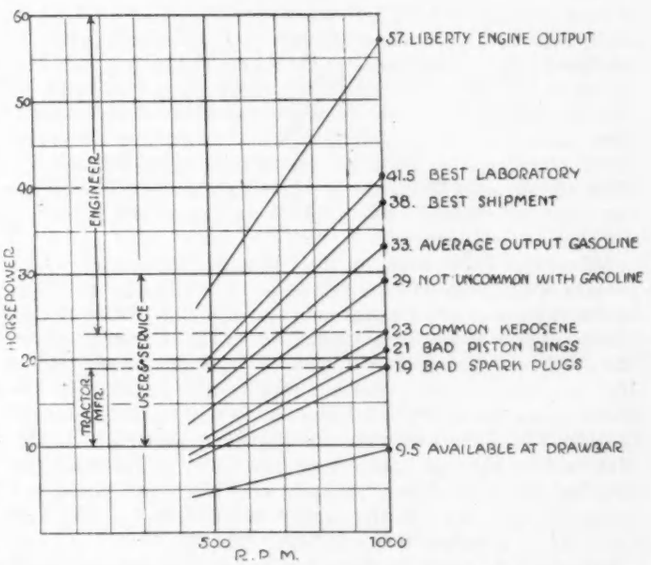


Diagram of the Power Available in a 60-Hp. Engine with Different Fuels and the Various Persons Vitally Interested

The engineer gets another raw deal in the service department. I have sent service men to ten places recently where they were having trouble with our engines. There was not a competent man to give first aid in one of the ten places, although one station was a general agency and repair station for five states.

When you have a good thing, stick to it. If you are working on kerosene, for instance, do not give it up. We are running in a circle now. It is a bad time, but there is great hope. Those of you who have worked as I have for 3 yr., can spare time for night work in the laboratory, trying to solve the problems of kerosene. Engineers who are willing to work, engineers who have produced the Liberty engine and all the other things that have made it possible for us to take Chateau-Thierry and start the war the other way, are bound to get somewhere.

The Discussion

C. E. Sargent:—It occurred to me when Mr. Horning was giving us the points of disparity on this diagram, that there is an explanation for the trouble which he deplores. The Liberty engine, which is a poppet-valve en-

gine, gives 57 hp., and the tractor engine only two-thirds of that, but there is really no difference in the thermodynamics. The pressure is the same and the speed can be made the same in both cases. I would like to ask Mr. Horning how he accounts for the discrepancy between a tractor engine giving its best horsepower and a Liberty engine giving its best horsepower. If I understand correctly what he has shown us, it does not seem that any comparison can be made between the two and I do not see what the mechanical differences are.

MR. HORNING:—The main differences lie in the combustion chamber and its ability to dissipate the surplus heat, and in the limitations of fuel. It is possible for them to carry compressions up to 140 lb. per sq. in. and I understand that with special fuels it is possible to carry these up to 250 lb. I also understand from Mr. Kettering that when they get up to 150-lb. compression the horsepower does not continue to increase. No doubt, as the radiation of heat varies as the fourth power of the absolute temperature and the specific heat of hot gases increases rapidly with temperature, the very high temperatures gained by the higher compressions are not available as power. For the truck we have an engine with the ordinary type of combustion chamber; it has a rough surface; it can be made in the overhead valve type with all the surfaces unfinished. It seems possible at the present time to get up to only about 100 lb. mean effective pressure, whereas the Liberty aviation engine will rise to perhaps 140 or 145 lb. mean effective pressure. I can see no other difference between them as far as the power of generation is concerned.

Of course, there is an element in a tractor engine which is very well taken care of in the aviation engine and that is the stiffness of the crankcase and the size of the crankshaft. Right there is a very interesting feature, which Mr. Milbrath has shown to good advantage in his paper. If I am not mistaken the connecting-rod bearing in the Liberty engine is 2⅝-in. diameter by 3¼ in. long, and in the Class B Government truck engine, around which Mr. Milbraith's designs are developed, the connecting-rod bearing is 2⅜ by 3 in. There is very little difference between the two and yet the output per cylinder is two and three times greater in the Liberty engine.

In the tractor engine the great value of crankshaft size is probably in the stiffness of the shaft. The engine must keep on working whether the bearings are taken up or not. It must meet the conditions of the farm whereas the Liberty engine in the hands of experienced mechanics, is taken down at regular intervals and the bearings if worn are thrown away, which is not true in tractor service.

The aviation engine has been brought to a very high state of efficiency as regards friction loss, a point that does not always have the necessary attention in the tractor engine. There is no doubt that the future holds great development in the line of horsepower, power that can be produced day-in and day-out, not the 41.5 but the 38 hp., regardless of conditions.

A very interesting thing happened in our experiments. I want to record it here, and perhaps start some good sport in a scientific line. While working in the dark with kerosene under very high compression, 90 lb. per sq. in., and the water discharge cut down so that the engine was sizzling hot and the radiator ready to burst, we were just about to take a photograph of the high pressures being developed, when suddenly a spark jumped from one side of the engine to another, a distance of some 20 in. It was an unexpected phenomenon and I immediately turned on the light to trace the source of the spark if possible. I found it started from the handle of the priming-cock and ended on some metallic object, I could not tell what. I have repeated that experiment many times and had 8 and 10 in. discharges from the priming-cock handle, always just at the time when we were getting the very highest pressure, 1300 lb., so high in fact that the copper tubing was ruptured and we had difficulty in holding the little aluminum mirror in the manograph to take the pressure. I have constructed several electrodes and placed them inside the combustion chamber to see if I could duplicate the phenomenon with an electrode of the proper shape to collect whatever charge there is. Thus far I have not succeeded. I have thought of a possible scientific explanation for the action but on such uncertain grounds that I take pleasure in laying the matter before you with the idea that there are some here who have studied deeper into the phenomena of ions than I, and may be able to give us some satisfactory explanation. Whether the burnt gases passing through the exhaust valve are charged with one sign of electricity, and whether, under the very high pressure and with the spark jumping in the combustion chamber, it is possible to collect a charge from the mixture and then dissipate it to the air along natural paths, are the questions to be answered. I shall be very glad to have the matter discussed either here or in writing. In it may lie one of the ways by which we can burn the heavier fuels. Perhaps, if we can get right after this charge which is disturbing conditions in the cylinder, we can burn our fuel in a much smoother and more perfect way. This is pure speculation, but I look forward with a great deal of pleasure to hearing from some of you on the subject.

CHARLES F. KETTERING:—Mr. Horning brought up a point or two on which I think I can throw a little light. The horsepower of aviation, truck and tractor high-duty engines needs to be given much consideration in the design. In the first place you cannot take an engine of 100 or 125 lb. compression and get 125 lb. mean effective pressure in it with any kind of fuel; it is fuel limitations rather than engine limitations that cause the difficulty. We built a Liberty engine of 210-lb. compression last year and ran it perfectly with explosion pressures no higher than with 100-lb. compression. This was done to ascertain if possible to what extent the fuel entered into the situation.

In the low-gravity fuels we have a type which breaks down into secondary compounds, some of which are highly detonating, and it is not an uncommon thing, as Mr. Horning has mentioned, to witness an extraordinary rise in explosion pressure. That pressure adds nothing to the energy of the engine; about the only thing it does is to put special duty on the bearings. You cannot run a Liberty airplane engine on ordinary gasoline, such as is used in automobiles, with a wide throttle, because you get bad hammering. For this 200-lb. engine we made up a fuel. You can build a fuel just as you do building blocks, using the ingredients in any way you wish. These made fuels did not behave badly. The explosion pressures were exactly the same whether we had 200 or 100 lb. compression in the engine. That may seem mysterious but it really is not. If you have a fuel which will burn by a single step from carbon or carbon dioxide or from hydrogen to water, the pressures can go no higher than the critical temperatures of the chemicals in combustion. You have a self-regulating fuel. The fuel we constructed for this very high compression has molecules of the same size. Any satisfactory fuel must have. The distillation curves, which are nothing but a manner of weighing molecules, must be closely studied.

Mr. Horning brought up the point that after you have run the compression above a certain point, you get no marked increase in horsepower. You should not expect it. About the only thing to be gained is a little better volumetric efficiency. So far as the explosion pressures are concerned, they are constant.

Here is an experiment that is worth trying. Take an engine of 75 or 100 lb. compression, put kerosene in it, and get it warm. It will hammer badly. Put 3 per cent of ethyl iodide in the kerosene, and even if you raise the compression of the engine to 125 lb. it will not knock. It will run just as smoothly on kerosene as on gasoline. The interesting question is: What does the ethyl iodide do? If some chemical reaction enters, what is it? We analyzed the situation, and found it simple. Iodine is a variable. Below 1200 deg. its vapor exists in molecular form; from 1200 on up to 2200 deg. it exists in atomic form. The energy required to change from molecular to atomic form just crushes off that critical temperature and prevents the formation of the secondary compound. If iodine did not cost so much it might be used to overcome the difficulty of burning kerosene. The number of British thermal units it takes to change iodine from molecular to atomic form is very small. Some one should work up or find a cheap substitute for it.

The knock which is heard in a cylinder running with a fuel that will crush without too great variation, at not much over the critical temperature, is not premature at all. It may come 5 or 10 deg. ahead of the top center or on the down stroke, more often the latter, since it takes a certain time to reach the specific heat of the gas and get up to the temperature where compounds begin to form. An analysis has shown us that the secondary compound which detonates and causes so much trouble is acetylene, one of the results of the combustion of a heavy molecule. If you pass kerosene through a tube of iron filings you will generate a certain amount of acetylene. We put a spectroscope in the cylinder and got a strong carbon line on the spectrum every time. We went further with the experiment, and found that the carbon lens was illuminated just when we got the peak pressures.

In experimenting on these fuels we started with benzol as a base, because it seemed to be the most degenerate fuel we could get. It has gone through the acetylene stage, and in itself is not a very good fuel, for the reason that it is high in carbon, so we put in a certain amount of hydrogen. Such a fuel is more nearly primary than any we have yet found, in that it burns by a single step from carbon to carbon monoxide, and from that to dioxide. It will always give exactly the same explosion, because as soon as it burns up to a pressure and temperature where the products disintegrate it quits burning.

All manographs produce a wavy line, often said to be due to the inertia of the indicator, but really due to the characteristic of the fuel. As one becomes accustomed to looking at the diagram one can tell by the number of wiggles exactly what kind of fuel has been burned.

I hope that I have given you some idea of why we get more power from a Liberty airplane engine than from the ordinary truck engine. We select a fuel which will not break down and which will not be detrimental under the pressure and temperature used. It is well to remember, also, that the cylinder walls of a Liberty engine are very much thinner than those of a truck engine, which has a better cooling effect. One thing the engine builders have never taken into consideration is the time rate of changes in temperature. You can heat a ½-in. radiator just as hot on the outside as a 1/6-in., but nothing like as quickly. With the rapidly occurring phenomena we must take heat out just as rapidly as it is generated, to prevent the temperature from going up.

I shall not attempt an explanation of Mr. Horning's spark. As he suggests, there is a most intimate relation between electricity and heat. If you take a copper plate and connect it with a steam pipe or some heating device on one side, and a cold-water pipe on the other side, so as to get a heavy transfer of heat across the plate, and then put an electro-magnet at right angles to this, you will deflect that heat transfer up and down just as you deflect an electric current; and if you put on a magnetic field, one side will run hot and one cold. There is an absolutely direct relationship between thermal conduction and electrical conduction. Copper is a good conductor of both electricity and heat. You will almost always find the same relationship existing; if you have a good thermal condition you have a good electrical condition.

There is an enormous amount of work to be done in studying the internal conditions of a cylinder, and it is only by improving our manographs and learning the chemical composition of our fuels that we shall ultimately get results. This work will be done, however, and I venture the prediction that within 5 yr. we shall be burning kerosene just as easily as we burn gasoline. The reason we have not made greater progress is that the problem so often proves to be just the opposite of what we thought it was. We have not solved this problem because we have not been working where it is.

It will be some time before we get the efficiency from an ordinary engine that we get from an airplane engine. In this work it is well to be able to make quick comparisons of some of these things. We have developed a scheme to figure rapidly on a lot of engines, basing our calculations on what we call engine power-factor. I will take a Liberty engine for illustration. It has a 5-in. bore; 5 squared is 25; times 7 is 175. Now, 175 multiplied by 1700, which is the normal rated speed of the engine, gives something like 290,000, which we call 29. In other words, if that engine has a power-factor of 1 it will give 29 hp., but that same cylinder gives 33, 34, or 35 hp. It has a power-factor of about 1.2, which is, by the way, the highest that has ever been attained with a commercial engine of any kind.

Taking a 3 by 5 in. cylinder, such as is used a great deal in motor-car work, three times 3 is 9; times 5 is 45. If we take for speed 2000 revolutions, we get about 9 hp. for a power-factor of 1. We know that the ordinary 3 by 5 in. engine does not give more than about 0.8 of 9 hp.; so you get a power-factor of 0.8.

When you have the power-factor, the figuring is very simple. Leave out the cylinder area and the π factor, and get these based on the power-factor. This is nothing less than considering the volumetric efficiency per cubic inch without actually turning it into cubic inches.

You will be surprised when you get to comparing different types of engines on that basis. You will find that kerosene engines all run down to a power-factor of about 0.6, for the simple reason that if the compression is pushed abnormally high disintegration of fuel follows, high pressures come in, and the bearings will not stand up.

We know that we can take an engine out when it is cold, step on the throttle and have a knock. For some reason the carbon knock has always been considered a mystery, but there is nothing strange about it. We have

done nothing but insulate the cooling system from the gases and introduce a longer time-factor. It takes longer for heat to get through; consequently, the temperature of the gases, even though the engine be cold, is higher than it would be if the engine were clean. We can make an engine knock just as easily on a cold as on a hot day, because of the time it takes to get heat past the critical temperature at which compounds are formed. When they disintegrate they knock.

The problems of engine knocks and carbureters are problems of fuel, absolutely. We use a fuel of a given gravity, but this does not mean that it will not knock. It is just like potatoes. You buy potatoes, and specify they must average 4 oz. per potato. Some weigh ½ oz., and some 2 lb., but the total weight divided by the total number in the bushel will be 4 oz. Fuel for the Liberty engine could not be anything like that. If you had a 4-oz. potato as your guaranteed potato, they would all have to be nearly 4 oz.

MR. HORNING:—In starting up a hill on a cold morning we step on the throttle and the engine knocks. That is exactly what we get when we are running the manograph. When we start the engine cold, with the heated manifold, we get the largest weight of gas in the cylinder; with the largest weight of mixture we get the greatest weight of oxygen and also the greatest compressions, which, of course, force the explosion pressures up. About 20 sec. after the start we get the really high pressures. As the engine and manifold get hotter the weight of charge entering the cylinder becomes less; hence we get less compression. Harry Ricardo, an English engineer, calls attention to the fact that the breaking down is more dependent on pressure than it is on temperature, which our experience indicates is the case.

Mr. Kettering called attention some years ago to the fact that in the analysis of exhaust gas you get a line of wonderful chemicals. I have noticed in our laboratory three distinct smells from the exhaust. If the exhaust is rich you get the characteristic smell that is so stifling. Gas in just the correct proportion gives another odor; a lean mixture, still another. I understand from Mr. Stratford that the analysis of lubricating oil in the bottom pan gives formaldehyde and very valuable disinfectants. These chemicals in the bottom of the crankcase were caught in the act of passing from one composition to another. They pass down into the crankcase as intermediate products. There is no doubt that we shall some day have a great industry built on extracting these valuable disinfectants from lubricating oils.

E. B. BLAKELY:—We have studied with moderate success for the last 3 or 4 yr. the problem of burning kerosene through the medium of the Hvid engine. I have not succeeded in interesting very many engineers in the investigation.

There is one very interesting feature about the Hvid engine. It has its own still. The steel cup is in effect a still, with ideal conditions for breaking down fuels, high temperature and high pressure. By altering the shape and volume of the cup, the size of the holes, and the amount of surface presented to the heat, we can distill off any fuel to the degree we want. By proper proportioning of the cup we can stop the distillation process before getting down to the heavy tars which cause most of the trouble. If engineers will give the principle a little thought, and investigate the method, they will learn something also of processes of handling heavy fuels. From this little still very close intimate information can be gained as to what is actually taking place.

ROADS FOR MODERN TRAFFIC

CHEAP transit for goods and passengers, it is becoming universally admitted, is an asset of enormous value in national life, and labor and capital expended in this direction are amply repaid. It is wrong to assume, as so many do, that reduction in the cost of carriage benefits only those who are immediately concerned. As a matter of fact, a reduction in the cost of carriage on any one article of general consumption is an advantage to whole communities.

It is now fully recognized that to an enormous extent the well-organized and rapid transport of men, munitions and supplies assisted largely in winning the war. The future prosperity of our country (England) may depend upon the rapid, adequate and economical movement of the necessities of life and the requirements of industry.

For some years yet it is quite possible that our railroads will offer advantages for the long-distance carriage of freight, but there can be no question that for journeys up to, say 50 miles, and occasionally longer, road transport would be greatly superior. To secure the advantages it offers and develop the possible traffic, it is essential that our roads be brought up to present standards and maintained in excellent condition.

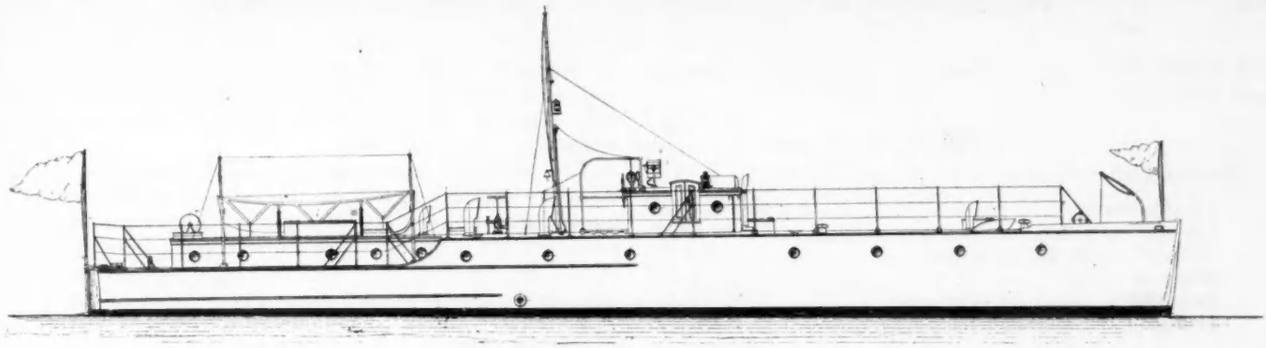
Until within recent years, the question of current and prospective traffic has not received adequate consideration from those who are responsible for the maintenance of our roads and, generally speaking, there has been a tendency to adopt similar methods of construction, irrespective of the type and volume of traffic as well as other conditions.

Even our recent methods of making road surfaces have been bad. Many can recollect the time when the traffic was expected to consolidate the materials used in repairs, obstructions being purposely placed on the roads to compel vehicles to run over and grind in the broken stone and flints. Now we have to adopt different methods, first the bicycle and afterward the motor vehicle having been instrumental in bringing this state of affairs about. We have also to thank the cyclist and the motor user, more particularly the latter, for the adoption of surface tarring and, subsequently, the use of bituminous surfacing, first employed for the mitigation of dust, but now for maintenance purposes. Although conditions have changed enormously in the last 15 yr., both in regard to the kind and volume of traffic, and in the construction and repair of roads, sufficient regard is not even yet given to the fundamental requirements of traffic in general. There must be adequate and stable foundations and lateral supports. This involves a study of subsoil and surface water drainage. There must be an impervious surface and a certain amount of resiliency.

The war has taught surveyors and, it is to be hoped, their governing bodies also, that capital expended in the proper manner on roads is a good investment. The cheapest road may in the end prove to be the dearest. Alignment, foundation, gradient and width, the camber and surfacing of roads, all still need improvement and development. There is the greatest need for good engineering in the adaptation of roads in these respects to the requirements of modern traffic.

—H. T. Chapman, *The Commercial Motor* (London).

Vol. IV May, 1919 No. 5



ELEVATION OF THE 80-FT. BRITISH M L CHASER

Automotive Applications of Marine Engines in the War

By GEORGE F. CROUCH[1] (*Member*)

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPH

THE object of this paper is to present to the Society a description of a few of the boats and engines which have been of service to the Allies and to the United States during the war and to draw conclusions as to the effect of the experience gained with these boats on the design of hulls and engines for general marine use.

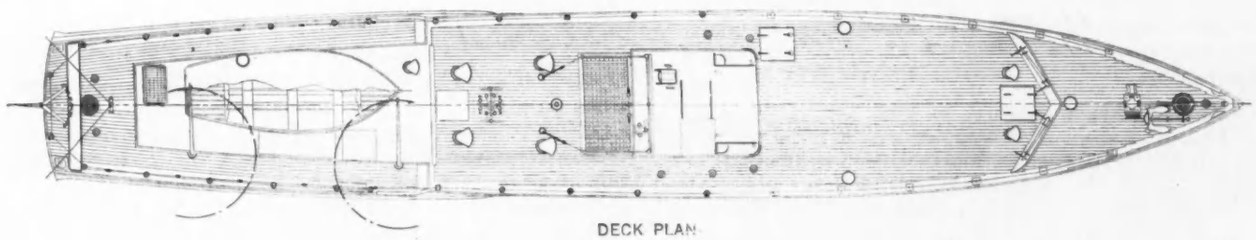
THE BRITISH M L CLASS

When it became apparent that the submarine offensive was a large part of the German plan, the British naval authorities decided that one of the most effective defensive measures consisted of a large fleet of small motor boats of good speed and seagoing qualities, which could search out the submarine and destroy it with depth bombs. For the amount of money expended, this scheme would provide a patrol over an immense sea area and because of their shallow draft the boats would be immune from torpedo attacks.

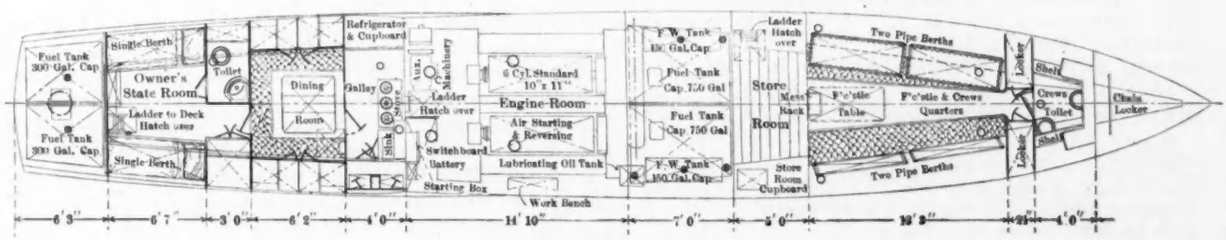
Plans submitted by American manufacturers were approved and the work of construction started. Within 488 days one American company delivered the entire order of 550 of these boats to the British Government, and additional orders from other Allied nations have since brought the total up to about 720 boats built by them to this design.

Their remarkable success in hunting the submarine and in working in conjunction with the larger naval vessels has been even more surprising to those of us who have followed motor boat work than to the uninitiated. It is not my intention to go into the details of the part these boats played, for that can be found in many stories already in print, but I cannot refrain from mentioning that they had a big share in the marvelous exploits of

[1]Technical editor, Motor Boat Publishing Co., New York City.



DECK PLAN



INTERIOR ARRANGEMENT

DECK AND INTERIOR PLAN VIEWS OF THE 80-FT. M L CLASS

the British Navy against the submarine bases of Ostend and Zeebrugge.

DETAILS OF THE M L CLASS

General Dimensions—

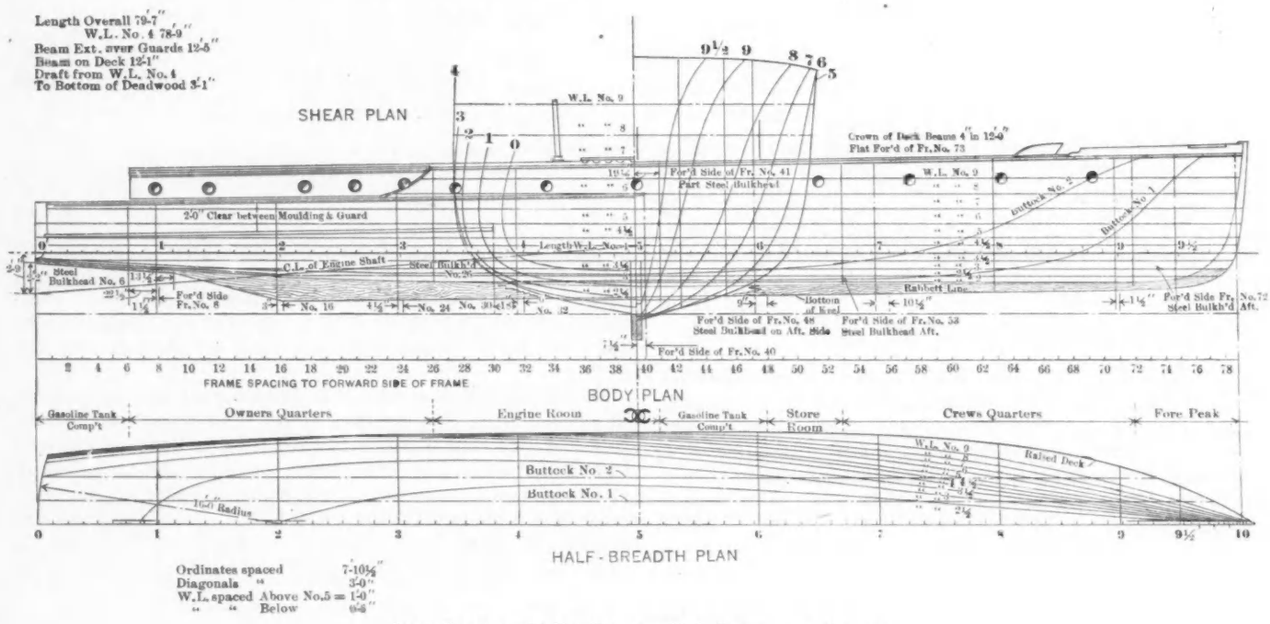
Length overall	79 ft. 7 in.
Length on water-line	78 ft. 9 in.
Extreme beam over guards	12 ft. 5 in.
Beam on deck	12 ft. 1 in.
Draught to bottom of deadwood	3 ft. 1 in.
Full-load displacement	78,000 lb.

Construction The hulls are lightly built, but are elastic and strong. In estimating their strength it must be remembered that the strength of small wooden vessels depends more upon their fastenings and the accuracy with which the parts are fitted than on the use of large and heavy parts. To speed up construction, every piece of wood in the hull was drawn out in detail and prepared in advance of the time it was required on the boat.

The steel bulkheads at the ends of the gasoline tank compartments are made gasoline-tight by careful workmanship and the use of a special paint composed of litharge, glycerine and shellac.

The outboard profile and arrangement plans of this class are shown. It will be noticed that the difference in appearance between one of these boats and a modern express cruiser of about the same size and power, is slight, except for the long fore deck of the M L class, which is kept clear of all obstructions to give a wide angle of fire to the short caliber 13-pounder gun mounted just ahead of the low chart-house over the midship fuel tanks. This gun is not shown in the plan, and it may be noted that in the later boats it was found necessary to build up a permanent shelter for the helmsman just aft of the trunk.

The line drawing is also reproduced. In form these boats are nothing more than big runabouts. In fact, if the scale were changed to give a length of about 35 ft., they would have not only the proper proportions, but about the correct displacement for a high-speed runabout



LINE PLAN OF 80-FT. BRITISH M L SUBMARINE CHASER

Principal Scantlings

Planking, yellow pine 1⅛ in. thick

Frames, white oak steam-bent, 1¾ in. sided by 1¾ in. molded, spaced 12 in. center to center. Heavy frames at bulkheads, white oak, 2¼ by 2¼ in.

Deck planking, Oregon pine laid in strips 2⅝ in. wide by 1⅛ in. thick

Deck beams, white oak sided 1¾ in., molded 2½ in.

Keel, white oak sided 4 in.

Keelson, yellow pine 4 by 5 in.

Floors, galvanized wrought iron 1½ ft. wide, ¾ in. thick at center tapered to ⅜ in. at ends

Knees connecting frames to beams, wrought steel ⅜ by 3 in.

Upper clamp, yellow pine 1¾ by 4½ in.

Main clamp, yellow pine 1½ by 5½ in.

Hogging clamp, yellow pine 1½ by 5½ in.

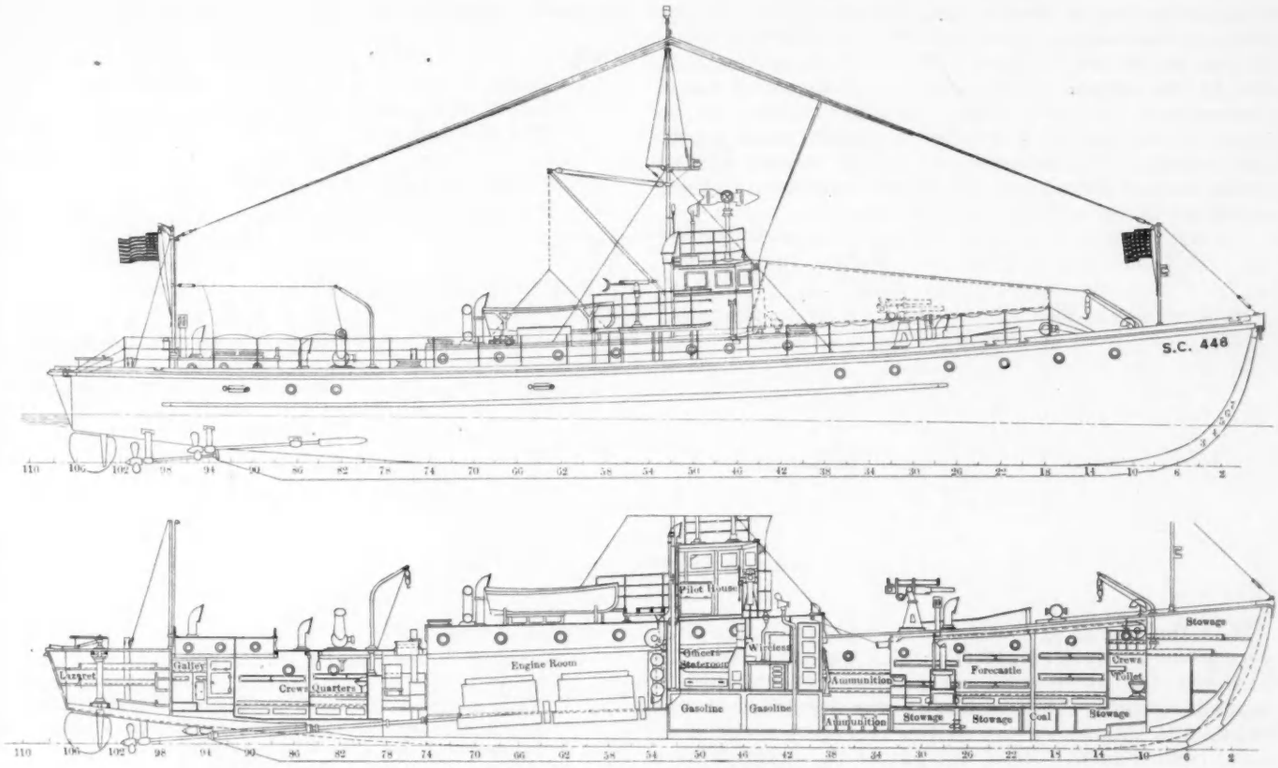
Side keelson, yellow pine 1¾ by 6½ in.

Bilge stringer, yellow pine 1½ by 4½ in.

Six steel bulkheads about ⅛ in. thick placed at frames Nos. 6, 26, 40, 47, 52 and 71

of that size. The wide, flat transom, deeply immersed when the boat is at rest, produces a form of small resistance at high speed, but creates a big wave at slow speed. The bow lines are long and fine. This combination of wide stern and fine bow has never been considered a desirable type for outside work in heavy weather, but the results in this case have been surprisingly good. Irvin Chase, the naval architect who designed the boat, was forced to use this form because of the high speed for the power demanded by the British Government. Another form, perhaps a more conventional seagoing type, would have demanded increased power and reduced the radius of action of the boats materially. Considering the restrictions imposed by these requirements, there was no possibility of using any other type, and although the boats are very uncomfortable in a heavy sea, which is true of any small craft no matter what its model, not one of the class has been lost through stress of weather.

Armament The armament consists of a short caliber, 26-in. recoil, 13-pounder gun mounted on the fore deck,



OUTBOARD AND SECTIONAL ELEVATIONS OF THE UNITED STATES 110-FT. SUBMARINE CHASER

four or five depth bombs charged with 250 lb. of TNT, 16-lb. lance bombs and two machine guns. Recoil pressures are kept down in the 13-pounder by using a low muzzle velocity and an unusually long recoil. The depth bombs are dropped off the stern by a releasing apparatus.

Machinery The powerplant consists of a twin-screw installation of two six-cylinder, four-cycle, air-starting and reversing "Standard" engines having cylinders of 10-in. bore and 11-in. stroke. These engines, which are rated by the builder at 220 hp. at 460 r.p.m., are directly connected to the three-blade propellers, 42 in. in diameter by 63-in. pitch.

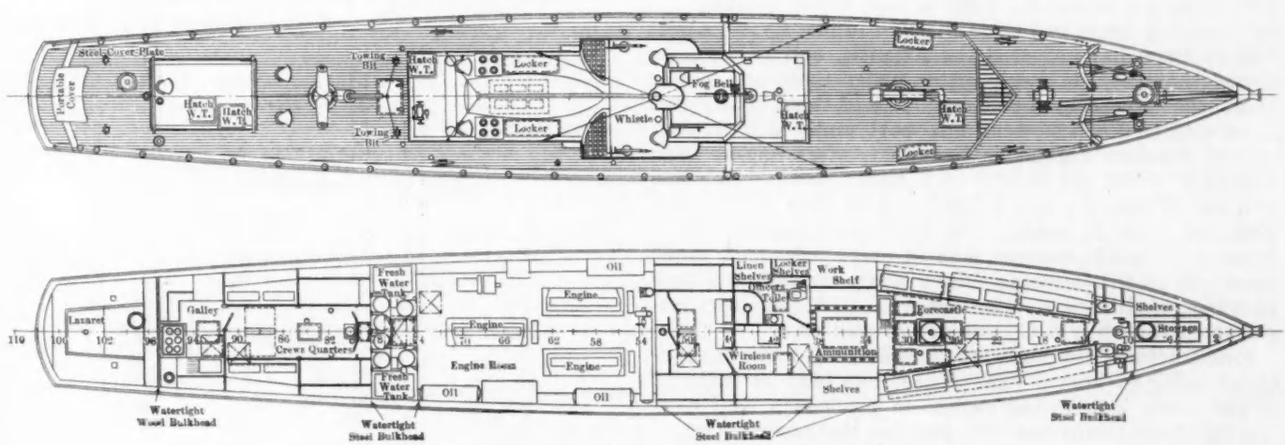
An auxiliary set includes an air compressor, a 4½-kw. generator and a bilge and fire pump. The two power cylinders of the auxiliary engine are 4½-in. bore by 4½-in. stroke, and have the air compressor cylinder between them. The fire and bilge pump has a capacity of about 50 gal. per min., and can be thrown in and out of action by a gear working in an eccentric mounting.

Gasoline is stored in built-in tanks in a compartment ahead of the engine-room and also in a smaller compartment at the extreme stern. The total capacity of the tanks is 2100 gal., giving a radius of action of 750 nautical miles at 19 knots, and 1000 nautical miles at 15 knots.

The maximum speed obtained on trial varied with the different boats from about 19¼ knots to almost 21 knots, due to the variation in the engines and to the depth of water on the courses over which the trials were run.

THE 110-FT. S C CLASS

Early in 1917, when war with Germany became inevitable, the Navy Department began to prepare for a great fleet of submarine chasers. Many boats were taken



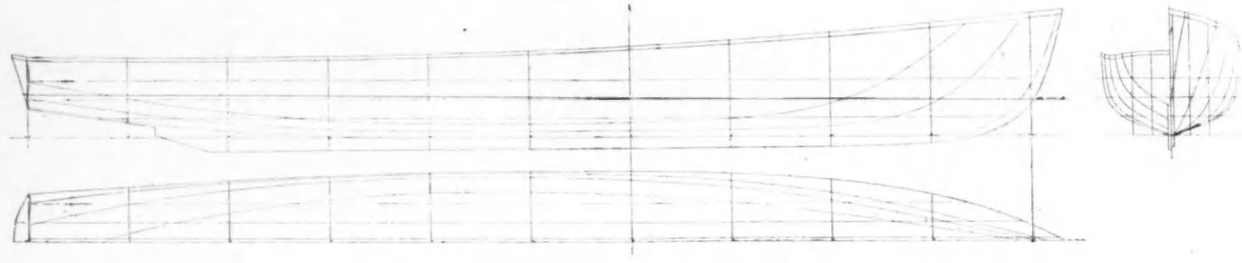
PLAN VIEWS OF THE UNITED STATES 110-FT. SUBMARINE CHASER

over from private owners, and, although they did good work, it was soon realized that they were hardly a suitable type for the purpose. The Navy Department obtained the services of A. Loring Swasey, later Lieut.-Commander, a Boston naval architect responsible for many of the best of the privately owned motor yachts, and, working in conjunction with the Bureau of Construction and Repair of the Navy Department, he produced the design of the 110-ft. S C class.

DETAILS OF THE 110-FT. S C CLASS

General Dimensions

Length overall	110 ft.	
Length on designed load water-line	105 ft.	
Extreme beam over guards	15 ft.	4¾ in.
Beam to outside of planking	14 ft.	8¾ in.
Draught to bottom of deadwood	5 ft.	11 in.
Displacement, full-load, about	75 tons	



LINE PLAN OF 110-FT. SUBMARINE CHASER

With the results of the M L class as a guide, the S Cs were given a length of 110 ft., which was considered the maximum for which stock engines could be obtained in requisite quantity. Then, too, it was decided that this length was about as great as the average boat-building yards could handle. Steel was out of the question as a material for construction because of the demand for large steel ships, which took all the available supply and filled all the steel shipyards. The first contracts were let April 16, 1917, and since this first order of a few more than 350 boats there have been smaller repeat orders, making the total of this class about 450. Contracts were placed all over the country, some even on the Pacific coast, whence the boats when completed were brought around through the Panama Canal. It is gratifying to the motor boat industry to know that the Navy Department realizes how these contracts were carried out.

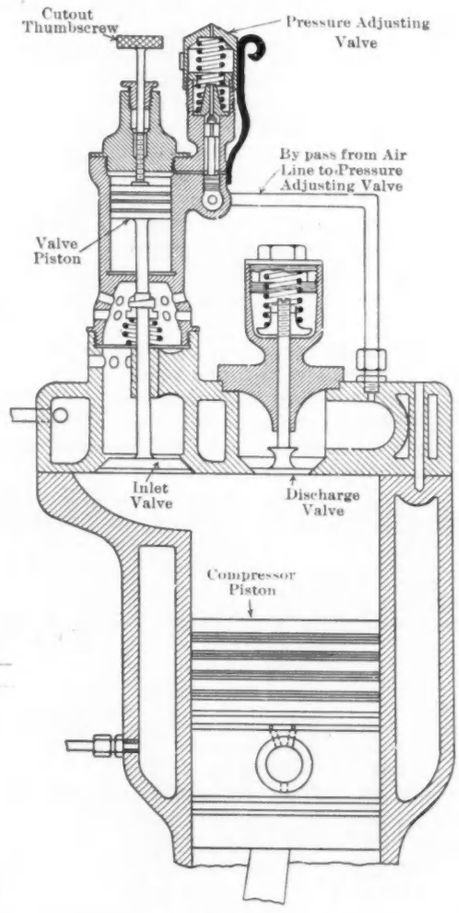
Since the armistice was signed many stories of these boats have found their way into print, and even the worst grumblers admit that they did more than their share. We have the statement of Secretary of the Navy Daniels that the S C vessels accounted for 40 per cent of the total number of submarines destroyed by the Navy; the fleet of converted yachts is credited with 30 per cent and the destroyers with 20 per cent. The chasers were out with the battleship fleet in the worst weather experienced in years and came through in fine style. About 235 of them have crossed the Atlantic, and it has been found that they do much better under their own power than when towed by a consort. One of them, which had been sold to France, went into port under a makeshift sail of blankets rigged on her mast, after having been separated from her convoy in a heavy storm. She had run out of gasoline and oil and was 39 days in reaching port, but made it safely. The boats have been tested in every conceivable manner, and in every case have made good. In all the immense shipbuilding, aircraft and tank program, nothing has come closer to fulfilling every expectation than this S C class of 110-footers.

Construction The hulls are substantially built, the material being of liberal size. There has been no attempt to cut down weight but rather to produce a boat that can stand up to any sea. In general, the construction is heavier than on yachts of the same size and power.

Principal Scantlings

Planking, yellow pine 1¾ in. thick

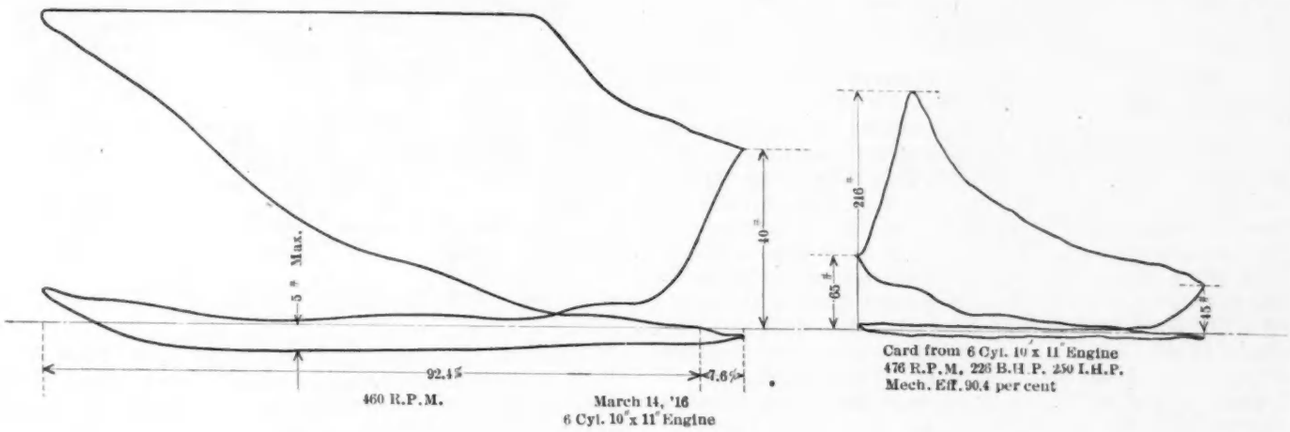
Frames, white oak steam-bent, sided 2½ in., molded 3 in., spaced 12 in. center to center. Heavy frames at bulkheads and at points where special strength is needed 4 in. sided by 3 in. molded

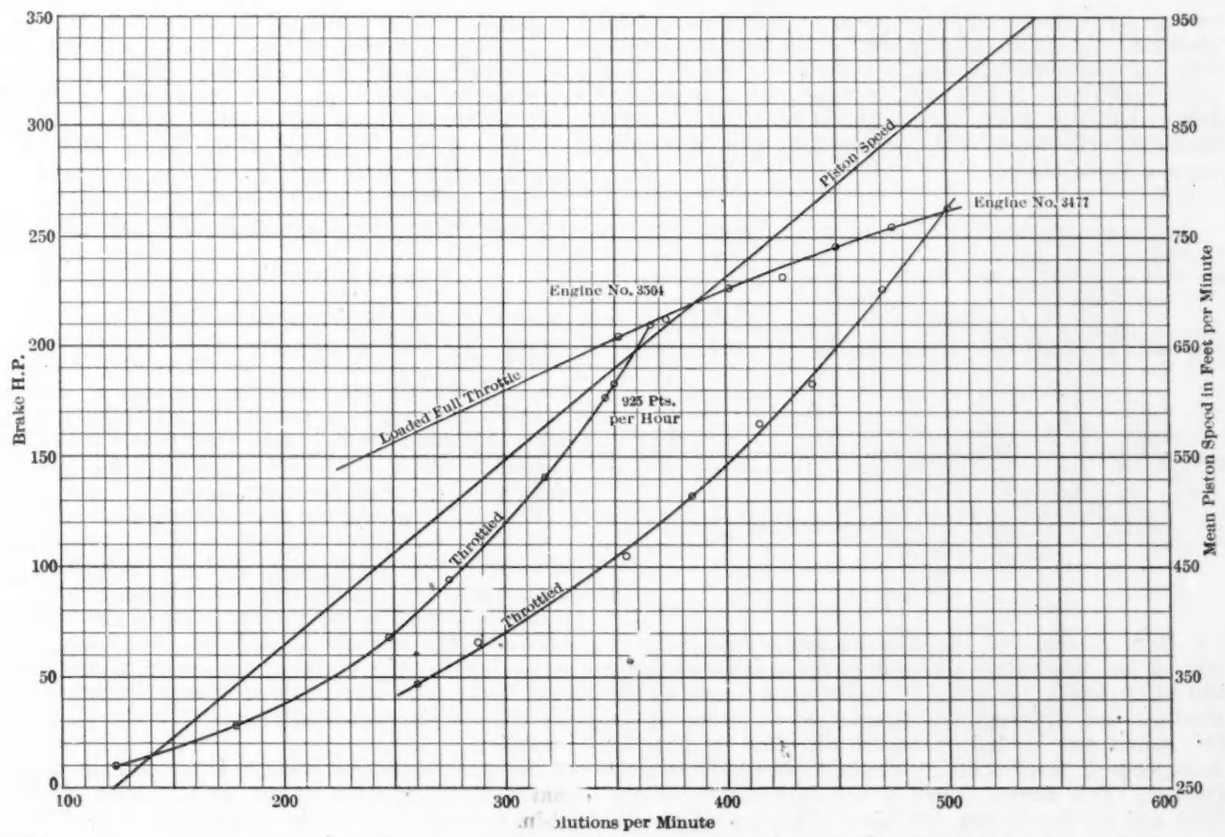


AIR COMPRESSOR

Deck planking, Oregon pine laid straight fore-and-aft in pieces 1⅝ in. thick and 3 in. wide
Keel, yellow pine sided 7 in., depth according to plans
Keel battens, white oak sided 9 in. by 8 in. molded
Floors, white oak regular floors on every frame 2 in. thick; heavy floors in engine space and under gun foundations 3½ in. thick
Upper clamp, yellow pine 3¼ by 3¾ in.
Main clamp, yellow pine 2¾ by 4¾ in.
Hogging clamp, yellow pine 2 by 8 in.
Six steel bulkheads about 7½ lb. per sq. ft. on frames Nos. 10, 33, 37, 53, 74 and 78

The outboard and inboard profiles of these boats is shown, as well as the deck and general arrangement. The forecastle is roomy and comfortable for a small boat, and is heated by a stove. This stove does more to make the crew comfortable than any one other item of equipment. Notice the wireless room on the starboard side over the gasoline tanks. The floor over the tanks is supposed to be vapor-tight, but the loss of one of these boats by an explosion caused by a wireless spark while taking on fuel confirmed the general belief that the gasoline tanks and the wireless should be kept as far apart as convenient arrangement will permit. Forced-draft blowers, driven by electric motors, ventilate the forecastle and the engine room when the hatches are closed in heavy weather. The galley is of ample size and very fully equipped, and the helmsman is well protected from the sea. Taken as a whole, there has been some apprecia-



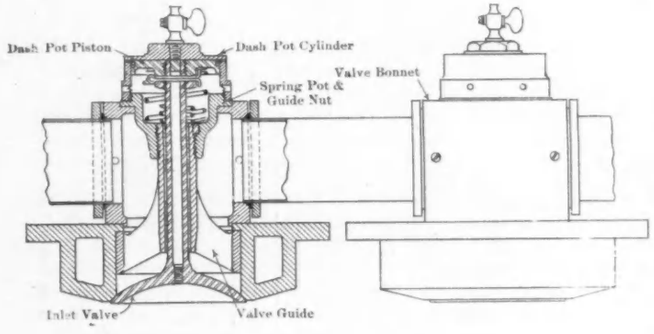


INDICATOR CARDS AND CHART OF TEST RUNS OF ENGINES USED IN THE UNITED STATES 110-FT. SUBMARINE CHASER

tion of what a few comforts mean to the efficiency of the crew of such a boat. Comfort is comparative, however, and the landsman would consider the life very hard until inured to it. The boats carry a crew of two officers and twenty-four men.

The line drawing reproduced is not an official plan, but is a close approximation to the form. The lines show a form which all experienced men will immediately accept as an excellent one for sea work. The water-line forward is fuller than in the M Ls and the stern much finer. All sections show a sharp rise of floor, which becomes even sharper at the ends. At the stern there is a transom much like that of a dory in shape. The heavy weights of the machinery, fuel and armament are kept well in toward the center of the length, so that the bow can rise easily and quickly to the sea. Owing to the fine lines of the after body, there is a tendency for the boat to "squat" at top speed.

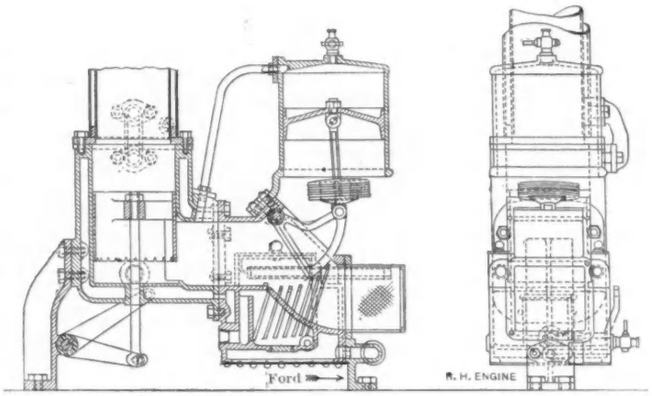
Armament The armament consists of a 3-in. Poole gun of 23 calibers, having a 28-in. recoil, mounted on the fore deck, two machine guns mounted on the wings of the bridge and a depth charge projector, commonly called a Y-gun, on the after-deck. Six depth bombs containing 300 lb. of TNT are carried. The 3-in. gun is much the same as that used on the British M Ls and can be converted into an anti-aircraft gun if necessary. The Y-gun is the unique feature of the armament. It takes its name from its shape, which is exactly that of the letter Y with arms pointing out to each side at an angle of about 45 deg. from a common chamber at their junction. This chamber is provided with a breech mechanism which takes a blank 3-in. shell, and when fired it blows out plungers fitting into the upper ends of the arms of the Y. These plungers carry the depth bombs on their outer ends, and bombs, plungers and all are shot overboard. This device places a charge on either side of the assumed position of the submarine, so that one or the other of the bombs is almost certain to "get it." All horizontal recoil is balanced, leaving only a downward thrust, which is easily taken care of by pillaring under the deck. The depth bomb, not the 3-in. gun, is the real weapon of the chaser.



INLET VALVE

A large measure of the effectiveness of the boats in hunting out submarines was due to remarkable listening devices by which the sound of a submarine could be determined and differentiated from that of other ships. This sound was located exactly in direction by plotting the reports of three boats in constant communication by wireless. This device is one of the dark secrets of the Navy and no details are available. The use of an engine which could be stopped and started instantly contributed to the efficiency of the installation of the device on these boats.

Machinery The boats are driven by triple screws each directly connected to a six-cylinder 220-hp., air-starting and reversing "Standard" engine. This is exactly the same engine that was used in the British M Ls, and was already being produced in quantity when our chaser program was started. The original propellers were three-



DETAIL ARRANGEMENT OF THE VAPORIZER

bladed, 36-in. diameter by 63-in. pitch; later changed to 39-in. diameter by 57½-in. pitch. Even these seem small for the power of the engine. The center engine can be uncoupled from its propeller shaft to allow the wheel to turn without dragging when the boat is cruising under the two wing screws. The auxiliary machinery set is a duplicate of that in the M Ls, previously described.

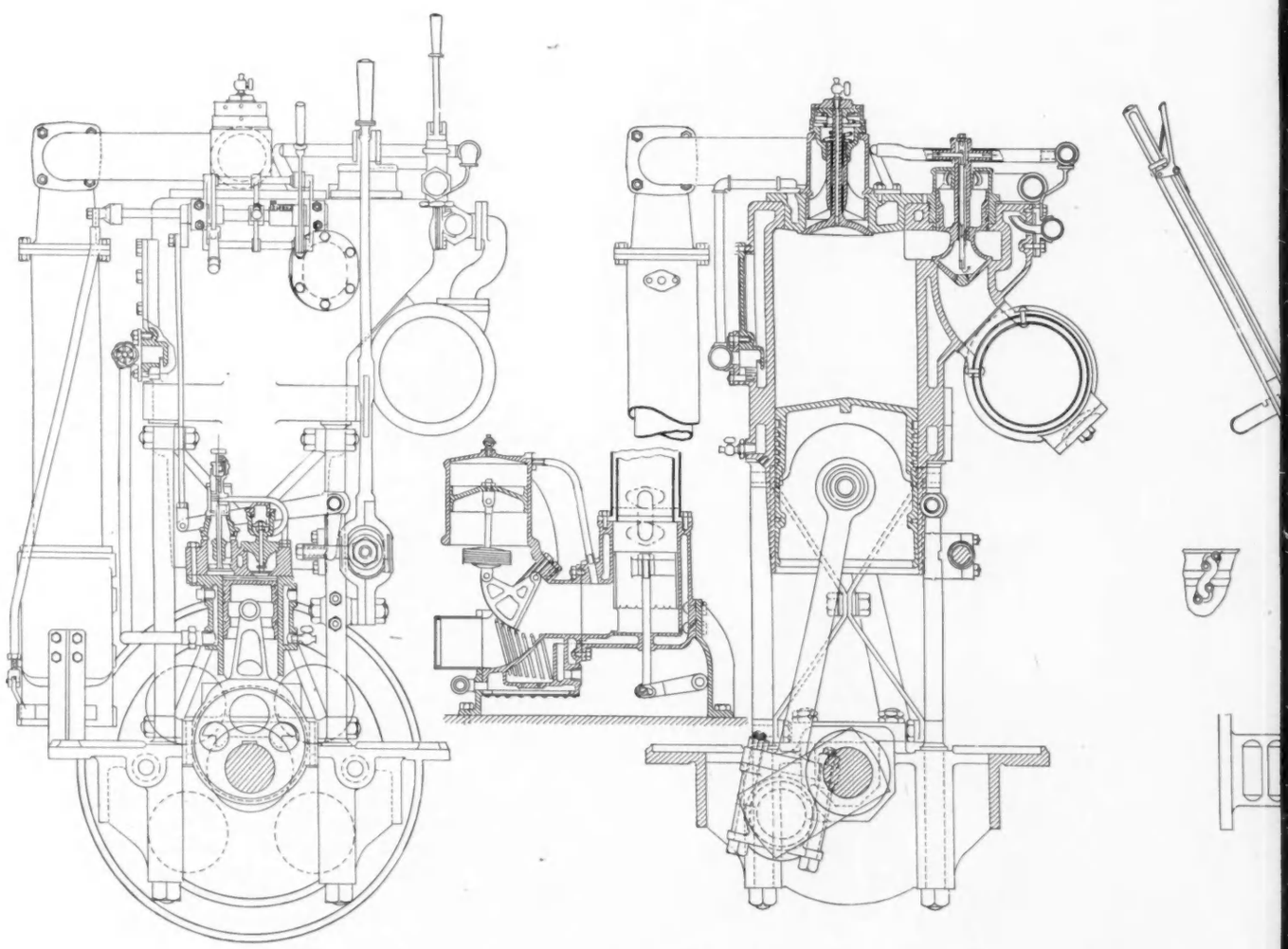
Gasoline is carried in four large shaped tanks fitted in the compartment forward of the engine room under the floor of the officers' quarters. The total capacity is 2400 gal., which gives a radius of action of about 1000 nautical miles at a cruising speed of 12 knots. The maximum speed with all three engines running is between 16 and 17 knots. About 1½ to 1¾ knots more is obtained under all three engines than under the two wing engines alone.

THE 220-HP. STANDARD ENGINE

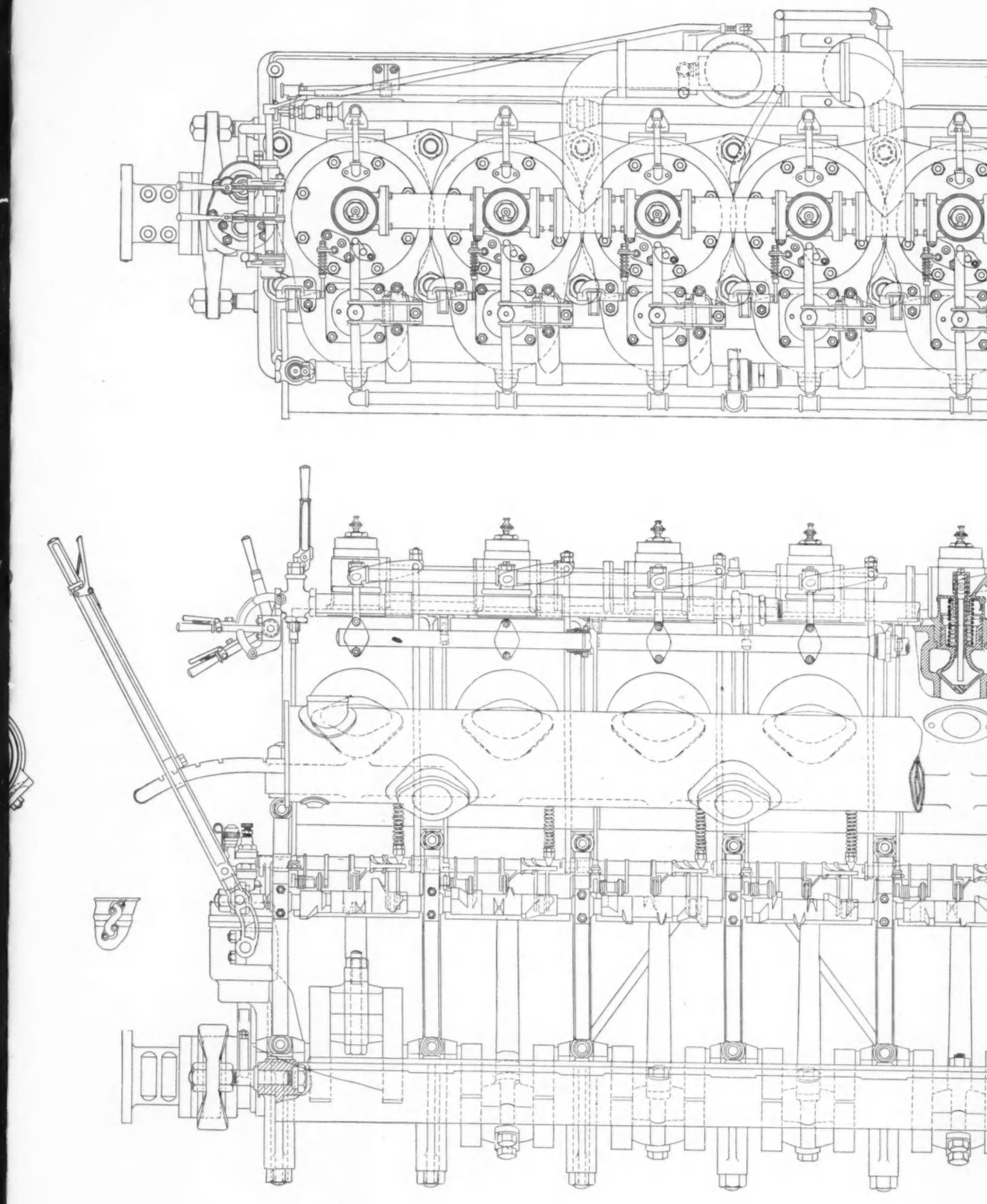
This engine, used on both M Ls and S Cs, is a stock model. In 1904 thirty small steel torpedo boats about 100 ft. long were built for the Russian Navy and were powered with the early model of this engine. The present model is changed in some details, but nothing of any account has been altered since that time. I believe it is unique to find a time-tried stock machine used in such quantities in any Government work.

The job of producing all these engines was immense even with the best of modern production methods. In a little over 3 yr. the Standard Motor Construction Co. has delivered about 700,000 b.hp. of this model alone. That is power enough to drive twenty-five of the large superdreadnaughts such as the Arkansas and more than will be needed for our proposed battleship program for the next 3 yr. It is only by making such a comparison that the size of this submarine chaser undertaking is comprehended.

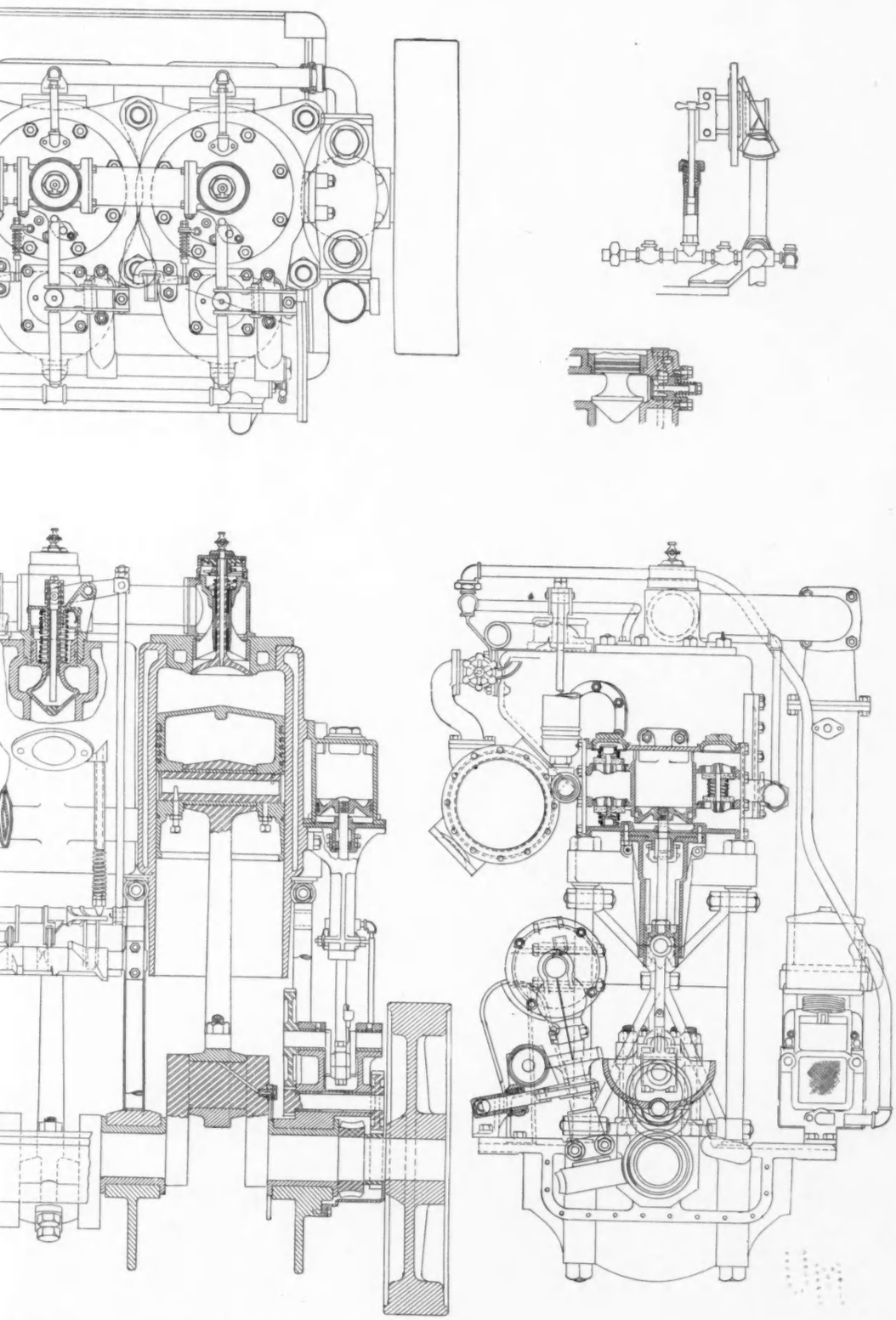
The general arrangement of the engine shows the characteristic features of the design. The cylinders are 10-in. bore by 11-in. stroke. The normal speed for which the engine is designed is 460 r.p.m. Its rating at this



PLAN, END AND SIDE ELEVATIONS AND PARTIAL SECTIONA



PARTIAL SECTIONAL VIEWS OF THE 220-HP. INTERNAL-COMBUSTION ENGINE USED ON THE UNITED STATES



STATES 110-FT. SUBMARINE CHASER.

speed is 220 b.hp., but the actual power is close to 250. The weight of the complete engine is 6300 lb.

Starting and reversing are accomplished by admitting air through a cam-operated valve into a small chamber, from which it passes into the combustion chamber by forcing open a spring-loaded non-return check-valve. The cam-operated valve is timed to admit air on the regular working stroke, and, as it is exhausted on the regular exhaust stroke, it does not interfere with the suction or the compression of the gasoline-air mixture. If the mixture ignites, the resulting pressure within the cylinder holds the check-valve against its seat and prevents the entrance of starting air, even though the mechanically operated air-valve be open. As soon as the

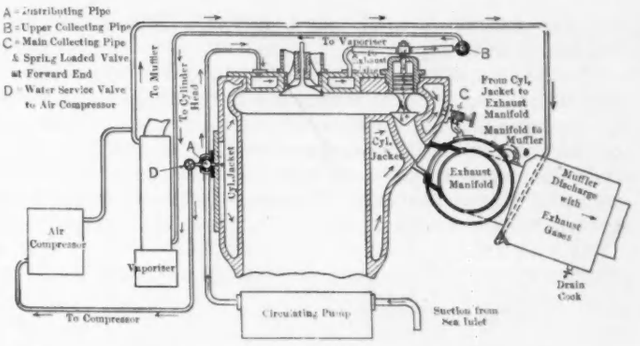
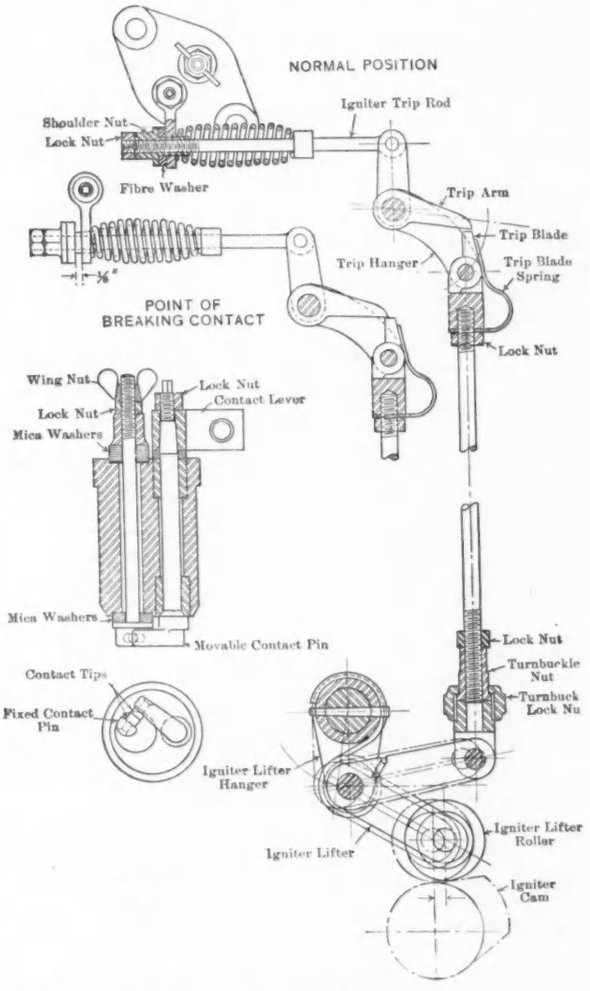


DIAGRAM OF CIRCULATING WATER SYSTEM



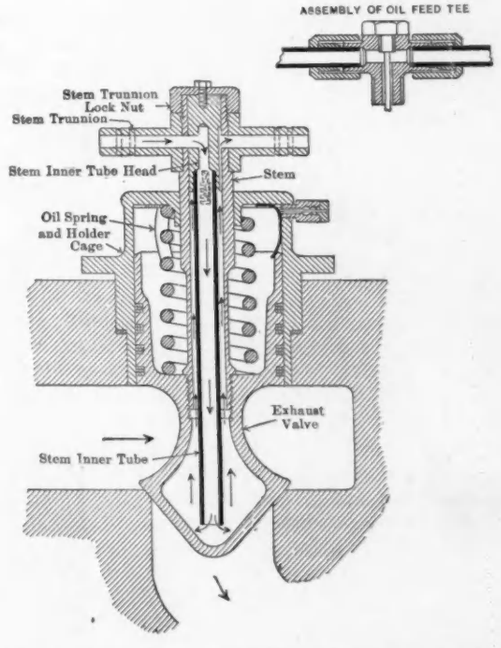
IGNITER GEAR USED ON THE ENGINES OF THE UNITED STATES 110-FT. SUBMARINE CHASER

engine is firing regularly, the camshaft is shifted longitudinally to running position, for either the ahead or astern direction, and this shift moves the air-valve cams out of line with the followers. The camshaft, which operates the igniters and exhaust valves, as well as the air-starting valves, is shifted longitudinally by a long lever at the after end of the engine. This is shown in the neutral position for ahead or astern motion, thus bringing into operation entirely different sets of cams timed to function properly for the desired direction of rotation.

It should be noted that when the engine is stopped by cutting off the ignition and the camshaft is brought to neutral position after having been run in one direction, it can be started in the reverse direction nine times out of ten without using any air, since the shift of the camshaft produces a spark at the proper igniter if the switch is closed before the camshaft is shifted. This reversing is so quick and powerful that the 110-ft. chaser can be stopped in a couple of lengths when going full speed ahead.

Air for starting and reversing is stored at a pressure of 250 lb. per sq. in. in cylindrical steel tanks, in which the desired pressure is maintained by a compressor at the after end of the engine.

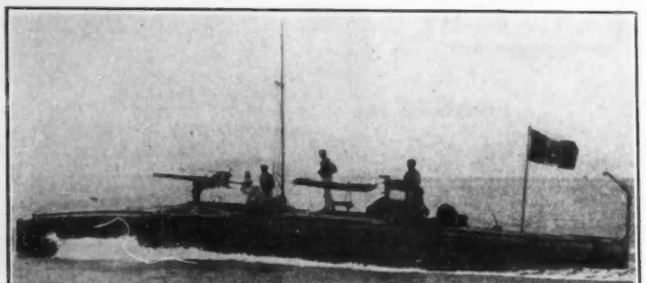
Automatic inlet valves, a type long ago discarded in automobile work where great speed range is required, are used on the engine. In these slow-speed engines, automatic valves function efficiently, as can be seen by reference to the low scale indicator card reproduced. These inlet valves have a clear diameter of 4½ in. and are fitted with a piston on the upper end of the stem working in a dashpot to prevent fluttering and hammering, and with a stiff bumper spring to limit the lift. It may be of interest to note that the builder of the engine is about the only builder of marine engines now employ-



DETAIL ARRANGEMENT OF THE WATER-COOLED EXHAUST VALVE

ing the automatic inlet valve, and this is used only on the heavy-duty types.

The details of the water-cooled balanced exhaust valves are also shown. These valves are lifted from their seats by rocker-arms acting on trunnions attached to the top of the valve-stem. The rocker-arms are actuated by pull-rods connected to the cam-followers. Cooling water enters and leaves the valve through the trunnions, which are connected by short lengths of rubber hose to the



THE TYPE OF SUBMARINE CHASER USED BY THE ITALIAN NAVY

supply and discharge pipes. The valve has a clear diameter of 3½ in. and a lift of ¾ in. on the ahead motion and ½ in. on the reverse. About 90 per cent of the pressure of the valve against its seat is neutralized by the balance piston.

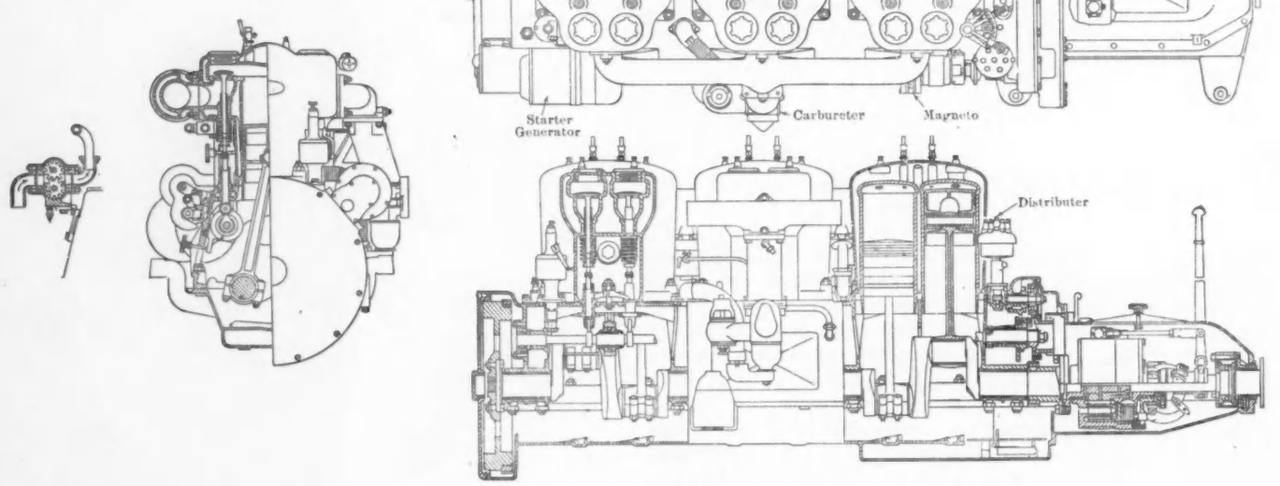
Make-and-break low-tension ignition is used. Current for ignition when starting the engine is taken from a storage battery, and for running is supplied by a low-tension alternating-current magneto driven by the engine.

Cooling water is taken from the sea and is forced through the jackets by a large double-acting plunger pump mounted at the fore end of the engine, driven at one-fourth crankshaft speed.

The carbureter is of special construction. It will be noticed that the fourteen spray nozzles are uncovered in sequence by a curved shutter, lifted by the vacuum above a piston working in a cylinder which communicates with the mixing chamber by a tube. This carbureter is without adjustment other than that obtained by changing the weight to be lifted by the piston. No float is used, as the gasoline is pumped into the bowl from a service tank placed below the carbureter level and the surplus delivered to the bowl returns to the tank through an overflow pipe. The air supply is not heated, but both the carbureter and the riser from the carbureter are jacketed with hot water. For easier starting in cold weather the cooling water discharge from the small auxiliary engine can be turned into these jackets. The main moving parts are lubricated by individual oil leads from a force-feed lubricator, each lead being set to deliver the requisite amount of oil direct to the part. Minor parts are oiled by hand about once an hour. Approximately 1440 hp.-hr. are obtained from 1 gal. of lubricating oil. Sheet-metal plates are fitted outside the steel column framing to prevent oil from splashing around the engine room, and a sheet-metal pan under the bed-plate keeps the oil out of the bilge.

An indicator card taken at 476 r.p.m. is reproduced. This card is not at all satisfactory, as it shows strongly the effect of the inertia of the piston, pencil gear and drum of the indicator, but it is given as the only one available at present. A maximum compression of about 65 lb. per sq. in. gage is obtained with a combustion chamber volume of 311 cu. in., a compression ratio of 3.87. An analysis of this card shows a volumetric efficiency of about 85 per cent after allowance for inertia errors.

The results of tests with a hydraulic brake are given. The curves obtained by throttling will follow somewhat the same law as if the engines were connected directly to the propellers. Fuel consumption at full load is approximately 0.7 lb. of gasoline per hp.-hr., which will doubtless seem high to those who have been working with



PLAN AND ELEVATION VIEWS OF THE 180-HP. ENGINE USED IN THE ITALIAN SUBMARINE CHASERS

engines having 100-lb. compression and over, but it is exceedingly satisfactory in actual service.

58-Ft. Italian Chasers

A type of boat entirely different from anything built in this country for chasing submarines is that which the Italians have used in the Adriatic. Although the hulls were designed and built in Italy, the motive power consists of a pair of 200-hp. eight-cylinder Sterling engines made at Buffalo, N. Y. The boats are 58 ft. long, 9 ft. wide and draw 30 in. The total weight of the complete boat with equipment is about 30,000 lb. To get strength with minimum weight, the planking is in three layers with canvas between each. The form of these boats is similar to a concave V-bottom runabout with the chine sweeping up forward to the stem head. The concave of the forward sections is very pronounced. They are said to make a speed of 26 knots. The boats are armed with a small high-power gun forward, which can be elevated for anti-aircraft use, two machine guns aft, and a number of mines. It has been reported that it was boats of this class, carrying deck torpedo tubes, that entered the harbor of Pola and destroyed two Austrian battleships.

The Sterling Engine

The engines in these boats are in decided contrast to the heavy-duty type used in our chasers, and in all their details approximate the heavy automobile or truck type. The general arrangement of a six-cylinder model of this engine is shown. The cylinders, 5½-in. bore by 6¾-in. stroke, are cast in pairs and are of conventional T-head design, with long water-jackets extending to the base flange. When built for high-speed work, the engine develops 180 hp. at 1200 r.p.m., and 200 hp. at 1400 r.p.m. Its total weight, including reverse gear, electric starter and generator, is 2400 lb. In sharp contrast to the open construction of the 220-hp. Standard engines, this Sterling engine is entirely enclosed, even to the flywheel. An electric starter which engages with teeth cut in the rim of the flywheel is used. Reversing is obtained by a clutch and reverse gear housed in an oil-tight case and lubricated by oil under pressure led through the hollow crankshaft. The ignition system consists of a high-tension dual two-spark magneto, the plugs being placed in water-jacketed bosses in the cylinder-heads. Two carbureters are used, each feeding a set of four cylinders. All parts of the engine are lubricated by a self-contained system which forces oil under pressure through the hollow crankshaft to all main bearings. The oil collecting in the base is cooled by a water-jacket on the bottom of the sump and is filtered before being again pumped to the bearings. A counter-balanced type of crankshaft is used. Fuel consumption at full power is approximately 0.6 lb. of gasoline per hp.-hr.

Other Boats

There are many other craft which should be included in a complete summary of the activities of our marine engine and hull builders, but exact data have not been accessible on either hulls or engines. An important fleet of thirty-one boats 60 ft. in length was built by the Greenport Basin & Construction Co. Each boat was powered with three eight-cylinder Van Blerck engines. These boats were of V-bottom form and were required to exceed 25 knots on trial. They were armed with a Russian 3-pounder forward and two machine guns aft, and operated against submarines in the Black Sea.

The engines were 6-in. bore by 6-in. stroke with T-head cylinders cast in pairs. As they were installed in the boats, they delivered about 165 hp. each at 1200 r.p.m. The total weight, including electric starter and reverse gear, was about 2400 lb. In general characteristics this engine and the 200-hp. Sterling are similar.

Some Deductions from Chaser Experience

With regard to the hulls, the statement can be made that not one of the types described is suitable for commercial purposes except perhaps a modified form of the 110-ft. S C model. With added beam and much less power this model would make a splendid off-shore fishing boat, as it is essentially a seagoing type. Each one of the forms described lends itself excellently to conversion into privately owned yachts and cruisers, particularly the 80-ft. M Ls. Since speed was a requisite in all these boats, they carry more power than is advisable even for yacht work, and far more than can be used in commercial craft for the transportation of cargo.

The horsepower required to propel a boat varies approximately as the cube of the speed and may vary as the fourth, fifth or even the sixth power of the speed, if the form is not suitable for the speed. It requires as much power to get the last 1¾ knots in the 110-ft. chasers as it does the first 12 knots. When cargo is to be carried cheaply the speed must be kept down as low as the conditions of the particular route and trade will permit. The result will be a good-sized boat of lower power, and this boat must have a large, slow-turning propeller, since no one has produced or even suggested a high-speed propeller to work efficiently on a big boat of moderate speed.

To realize the advantages of lighter weight, reduced first cost, decreased space required and general ease of handling inherent in engines running between 400 and 1200 r.p.m., some sort of transmission must be used between the engine and the propeller-shaft. It may be a reduction-gear, an electric drive or a hydraulic transformer, but it is sure to come into use and rather soon.

With regard to the engines, I believe that all single-acting internal-combustion engines for marine work, from the largest Diesel to the smallest gasoline outfit, should have the base closed in almost air-tight, and that a part of the air supply to the carbureter should be taken from the base. The open-column construction is excellent if well closed in, but with even the best of engines some gas will blow past the pistons, and smoke from the oil on the walls and on the under side of the piston-head will fill the base, and unless this is closed in and ventilated through the carbureter, will get into the engine-room.

The air starting and reversing six-cylinder engine directly connected to the propeller has had many tests, but never one as severe as in the English and American chasers. It is an unqualified success. It is a most satisfactory solution of the starting problem and entirely eliminates the reverse gear, which becomes a cumbersome mechanism in large, heavy-duty engines.

New Series of Pipe and Screw Threads

THE duties assigned to the National Screw Thread Commission by Congress included ascertaining and establishing thread systems. To meet the requests of manufacturers for early information, tables of dimensions for the coarse, fine and pipe thread systems from the tentative report have been prepared in advance of the formal report and are printed below.

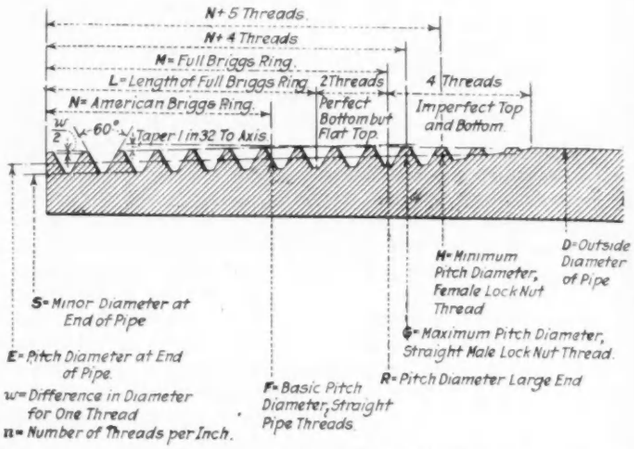
The complete initial or tentative report will include the following subjects:

(1) Form of Thread
(2) Thread Systems
(3) Classification and Tolerances
(4) Gages and Methods of Test
(5) Terminology
(6) Diagrams and Tables

The report is expected to be ready for distribution to and for consideration by the public about May 21, 1919, and is intended also to be the basis for discussion in an effort toward international standardization of screw threads.

A comparison of the standards given in the accompanying tables with those formulated by the British body doing similar work shows a number of slight differences. For example, the ½-in. coarse thread screw proposed by the Commission has 13 threads per inch while British practice calls for but 12.

An examination of the American and British pipe thread dimensions reveals a difference between the two series up to a 10-in. diameter. The angle of the thread for this class of work called for by the British standard is 55 deg. and the top of the thread is rounded, while the American standard thread is flat on the top with a 60-deg. angle. The latter is generally regarded as being better adapted to accurate quantity production since the flat top can be maintained more easily on both the threading tool and the work and the angle can be cut readily and correctly as it is exactly one-third of a circle. The 55-deg. angle of the British thread represents a compromise made over 50 yr. ago between the extremes of angularity, 45 and 65 deg., which were both in general use at that time.


N+5 Threads
N+4 Threads
M=Full Briggs Ring
L=Length of Full Briggs Ring
N=American Brigge Ring
2 Threads
4 Threads
Perfect Bottom but Flat Top
Imperfect Top and Bottom
w/2
60°
Taper 1 in 32 To Axis
H=Minimum Pitch Diameter, Female Lock Nut Thread
D=Outside Diameter of Pipe
S=Minor Diameter at End of Pipe
G=Maximum Pitch Diameter, Straight Male Lock Nut Thread
E=Pitch Diameter at End of Pipe
R=Pitch Diameter Large End
w=Difference in Diameter for One Thread
F=Basic Pitch Diameter, Straight Pipe Threads
n=Number of Threads per Inch

DETAILS OF THE STRAIGHT AND TAPER PIPE THREADS PROPOSED BY THE NATIONAL SCREW THREAD COMMISSION

The Values of the Various Quantities Are Given in the Table on the Facing Page

NATIONAL COARSE THREAD SERIES

Identification: Numbered and Fractional Sizes	Identification: n Number of Threads per In.	Basic Diameters, In.: D Major	Basic Diameters, In.: E Pitch	Basic Diameters, In.: K Minor	Thread Data: Metric Equivalent of Major Diameter, Mm.	Thread Data: p Pitch, In.	Thread Data: h Depth of Thread, In.
1	64	0.0730	0.0629	0.0527	1.854	0.0156250	0.0101
2	56	0.0860	0.0744	0.0628	2.184	0.0178572	0.0116
3	48	0.0990	0.0855	0.0719	2.515	0.0208333	0.0135
4	40	0.1120	0.0958	0.0795	2.845	0.0250000	0.0162
5	40	0.1250	0.1088	0.0925	3.175	0.0250000	0.0162
6	32	0.1380	0.1177	0.0974	3.505	0.0312500	0.0203
8	32	0.1640	0.1437	0.1234	4.166	0.0312500	0.0203
10	24	0.1900	0.1629	0.1359	4.826	0.0416667	0.0271
12	24	0.2160	0.1889	0.1619	5.486	0.0416667	0.0271
¼	20	0.2500	0.2175	0.1850	6.350	0.0500000	0.0325
5/16	18	0.3125	0.2764	0.2403	7.938	0.0555566	0.0361
⅜	16	0.3750	0.3344	0.2938	9.525	0.0625000	0.0406
7/16	14	0.4375	0.3911	0.3447	11.110	0.0714286	0.0464
½	13	0.5000	0.4500	0.4001	12.690	0.0769231	0.0500
9/16	12	0.5625	0.5084	0.4542	14.290	0.0833333	0.0541
⅝	11	0.6250	0.5659	0.5069	15.880	0.0909091	0.0590
¾	10	0.7500	0.6850	0.6201	19.050	0.1000000	0.0650
7/8	9	0.8750	0.8028	0.7307	22.220	0.1111111	0.0722
1	8	1.0000	0.9188	0.8376	25.400	0.1250000	0.0812
1⅛	7	1.1250	1.0322	0.9394	28.580	0.1428572	0.0928
1¼	7	1.2500	1.1572	1.0644	31.750	0.1428572	0.0928
1½	6	1.5000	1.3917	1.2835	38.100	0.1666667	0.1083
1¾	5	1.7500	1.6201	1.4902	44.450	0.2000000	0.1299
2	4½	2.0000	1.8557	1.7113	50.800	0.2222222	0.1443
2¼	4½	2.2500	2.1057	1.9613	57.150	0.2222222	0.1443
2½	4	2.5000	2.3376	2.1752	63.500	0.2500000	0.1624
2¾	4	2.7500	2.5876	2.4252	69.850	0.2500000	0.1624
3	4	3.0000	2.8376	2.6752	76.200	0.2500000	0.1624

NATIONAL PIPE THREAD SERIES, GIVING SIZES AND BASIC DIMENSIONS FOR TAPER AND STRAIGHT PIPE THREAD AND LOCK NUTS

Pipe Size in Inches	Threads per Inch n	Depth of Thread $0.8/n$	Pitch Diameter at End of Pipe E	Pitch Diameter at Gage Notch Basic Straight F	Maximum Pitch Diameter Straight Male Lock-nut Thread G	Minimum Pitch Diameter Straight Female Lock-nut Thread H	Outside Diameter of Pipe D	Thickness Full Briggs Ring M	Inches Thickness American Briggs Ring N	Pitch Diameter at Large End R	Difference in Diameter for One Thread w
1/8	27	0.0296	0.3635	0.3748	0.3840	0.3863	0.405	0.2638	0.180	0.3800	0.00232
1/4	18	0.0444	0.4774	0.4899	0.5038	0.5073	0.540	0.4018	0.200	0.5025	0.00347
3/8	18	0.0444	0.6120	0.6270	0.6410	0.6444	0.675	0.4078	0.240	0.6375	0.00347
1/2	14	0.0571	0.7584	0.7784	0.7963	0.8008	0.840	0.5337	0.320	0.7918	0.00446
3/4	14	0.0571	0.9677	0.9888	1.0067	1.0112	1.050	0.5457	0.339	1.0018	0.00446
1	11 1/2	0.0696	1.2136	1.2386	1.2600	1.2658	1.315	0.6828	0.400	1.2563	0.00543
1 1/4	11 1/2	0.0696	1.5571	1.5834	1.6051	1.6106	1.660	0.7068	0.420	1.6013	0.00543
1 1/2	11 1/2	0.0696	1.7961	1.8223	1.8441	1.8495	1.900	0.7235	0.420	1.8413	0.00543
2	11 1/2	0.0696	2.2690	2.2963	2.3180	2.3234	2.375	0.7565	0.436	2.3163	0.00543
2 1/2	8	0.1000	2.7195	2.7622	2.7934	2.8012	2.875	1.1375	0.682	2.7906	0.00781
3	8	0.1000	3.3406	3.3885	3.4198	3.4276	3.500	1.2000	0.766	3.4156	0.00781
3 1/2	8	0.1000	3.8375	3.8888	3.9201	3.9279	4.000	1.2500	0.821	3.9156	0.00781
4	8	0.1000	4.3344	4.3871	4.4184	4.4262	4.500	1.3000	0.844	4.4156	0.00781
4 1/2	8	0.1000	4.8012	4.8859	4.9172	4.9250	5.000	1.3500	0.875	4.9156	0.00781
5	8	0.1000	5.3907	5.4493	5.4806	5.4884	5.563	1.4063	0.937	5.4786	0.00781
6	8	0.1000	6.4460	6.5060	6.5372	6.5450	6.625	1.5125	0.958	6.5406	0.00781
7	8	0.1000	7.4400	7.5020	7.5340	7.5410	7.625	1.6120	1.000	7.5410	0.00781
8	8	0.1000	8.4340	8.5000	8.5310	8.5390	8.625	1.7120	1.063	8.5410	0.00781
9	8	0.1000	9.4270	9.4980	9.5290	9.5370	9.625	1.8120	1.130	9.5410	0.00781
10	8	0.1000	10.5450	10.6210	10.6520	10.6600	10.750	1.9250	1.210	10.6660	0.00781
12	8	0.1000	12.5340	12.6190	12.6500	12.6580	12.750	2.1250	1.360	12.6670	0.00781
14	8	0.1000	13.7750	13.8730	13.9040	13.9120	14.000	2.2500	1.562	13.9160	0.00781
15	8	0.1000	14.7690	14.8740	14.9050	14.9540	15.000	2.3500	1.687	14.9160	0.00781
16	8	0.1000	15.7620	15.8760	15.9050	15.9150	16.000	2.4500	1.812	15.9160	0.00781
18	8	0.1000	17.7500	17.8750	17.9060	17.9140	18.000	2.6500	2.000	17.9160	0.00781
20	8	0.1000	19.7380	19.8700	19.9020	19.9100	20.000	2.8500	2.125	19.9160	0.00781
22	8	0.1000	21.7250	21.8660	21.8970	21.9050	22.000	3.0500	2.250	21.9160	0.00781
24	8	0.1000	23.7120	23.8610	23.8920	23.9000	24.000	3.2500	2.375	23.9160	0.00781

The fractional sizes of the fine thread series conform to the S. A. E. Standard for this class of thread, but on the whole there is more variation between the American and British standards than is the case with either of the other two classes. The main reason for this lies in the fact that the basis of the American system is a finer line than that of the British. The so-called fine thread system of the British is in reality intermediate between the coarse and fine thread series proposed by the National Screw Thread Commission.

The question of reconciling these differences will be taken up at a series of conferences, the first of which, it is reported, will be held at London, early in June.

The dimensions for the basic size given in the foregoing table are based upon the following formulas:

The letters used in the formulas and the table refer to the drawing on the opposite page.

$$L = \frac{0.8D + 4.8}{n}$$

$$S = D - \frac{0.05D + 1.9}{n}$$

$$F = E + 16 - N$$

$$M = \frac{L}{b} + 2\left(\frac{1}{n}\right)$$

$$E = K3 + \frac{0.8}{n}$$

$$R = E + \frac{M}{16}$$

$$w = \frac{1}{16n}$$

NATIONAL FINE THREAD SERIES

Identification		Basic Diameters, In.			Thread Data		
Numbered and Fractional Sizes	n Number of Threads per In.	D Major	E Pitch	K Minor	Metric Equivalent of Major Diameter, Mm.	p Pitch, In.	h Depth of Thread, In.
0	80	0.0600	0.0519	0.0438	1.524	0.0125000	0.00812
1	72	0.0730	0.0640	0.0550	1.854	0.0138889	0.00902
2	64	0.0860	0.0759	0.0657	2.184	0.0156250	0.01014
3	56	0.0990	0.0874	0.0758	2.515	0.0178571	0.01160
4	48	0.1120	0.0985	0.0849	2.845	0.0208333	0.01353
5	44	0.1250	0.1102	0.0955	3.175	0.0227273	0.01476
6	40	0.1380	0.1218	0.1055	3.506	0.0250000	0.01624
8	36	0.1640	0.1460	0.1279	4.166	0.0277778	0.01804
10	32	0.1900	0.1697	0.1494	4.826	0.0312500	0.02030
12	28	0.2160	0.1928	0.1696	5.486	0.0357143	0.02319
1/4	28	0.2500	0.2268	0.2036	6.350	0.0357143	0.02319
5/16	24	0.3125	0.2854	0.2584	7.938	0.0416667	0.02706
3/8	24	0.3750	0.3479	0.3209	9.525	0.0416667	0.02706
7/16	20	0.4375	0.4050	0.3726	11.110	0.0500000	0.03248
1/2	20	0.5000	0.4675	0.4350	12.700	0.0500000	0.03248
9/16	18	0.5625	0.5264	0.4903	14.290	0.0555556	0.03608
5/8	18	0.6250	0.5889	0.5528	15.880	0.0555556	0.03608
3/4	16	0.7500	0.7094	0.6688	19.050	0.0625000	0.04060
7/8	14	0.8750	0.8286	0.7822	22.220	0.0714286	0.04640
1	14	1.0000	0.9536	0.9072	25.400	0.0714286	0.04640
1 1/8	12	1.1250	1.0709	1.0168	28.570	0.0833333	0.05413
1 1/4	12	1.2500	1.1959	1.1418	31.750	0.0833333	0.05413
1 1/2	12	1.5000	1.4459	1.3918	38.100	0.0833333	0.05413
1 3/4	12	1.7500	1.6959	1.6418	44.450	0.0833333	0.05413
2	12	2.0000	1.9459	1.8918	50.800	0.0833333	0.05413
2 1/4	12	2.2500	2.1959	2.1418	57.150	0.0833333	0.05413
2 1/2	12	2.5000	2.4459	2.3918	63.500	0.0833333	0.05413
2 3/4	12	2.7500	2.6959	2.6418	69.850	0.0833333	0.05413
3	10	3.0000	2.9350	2.8701	76.200	0.1000000	0.06495

LOCATING ENGINE TROUBLES WITH THE GEOPHONE

THE geophone, a listening instrument invented by the French during the war to detect enemy sapping and underground mining operations and for the location of enemy artillery, is capable of a number of interesting peace-time applications, according to the Bureau of Mines. These include the locating of miners who have been entombed after an accident, for bringing approaching tunnel headings together accurately, preventing accidents from explosions when breaking through and for locating underground fires and knocks in the valves and cylinders of automobile engines. When used for this last purpose the instrument, which is small and essentially a seismograph, should be mounted on a short iron rod that can be easily inserted in and around the machinery that is being tested.

The instrument consists of an iron ring of about 3½-in. diameter with a lead disk suspended in its center. A single bolt passing through two mica disks, one of which covers the top and the other the bottom of the ring, serves to keep the lead disk in the proper position. Two brass cap pieces, the upper one having an opening in its center to which is fastened a rubber tube, leading to a stethoscopic ear piece, complete the instrument. Bolts fasten the cap pieces to the iron ring and also serve to hold the mica disks in place.

If the instrument which in reality is nothing but a lead weight suspended between two mica disks cutting across a small air-tight box, is placed on the ground, the energy due to any pounding or digging that may be going on in the vicinity is transmitted as a wave motion to the earth, and these earth waves shake the case. The lead weight because of its mass and also because it is suspended between the mica disks remains comparatively motionless. Thus a relative motion is produced between the instrument case and the lead weight, the result being that the air in the instrument is compressed and rarefied and this in turn is carried to the ear drum through the rubber tube connecting the instrument with the ear piece.

Two instruments, one for each ear, are ordinarily employed, and by moving them a point can be found where the sound will be of the same apparent intensity in both ears, thus enabling the direction from which the sound is coming to be determined accurately.

The Unmined Supply of Petroleum in the United States[1]

By DAVID WHITE[2] (*Non-Member*)

ANNUAL MEETING PAPER *Illustrated with* CHART

THE justification of an estimate so highly speculative as must be that of the petroleum resources in the ground in the United States lies in the widening angle between the flattening curve of production and the rising curve of consumption. The standards of living, the industrial power and the prosperity of the country are dependent to so great a degree upon our oil supply, and the question of the adequacy and duration of this supply so directly concerns, at the present moment, the individual citizen as well as the public in general, that an estimate, even if it is but a scientific guess, based, with careful study, experience and judgment on the best information available, is imperatively necessary.

In response to the growing interest of the public four estimates of the oil resources of the United States have been made. In 1908 Dr. David T. Day,[3] then in charge of petroleum statistics in the U. S. Geological Survey, calculated the total amount of oil originally available in the ground as ranging somewhere between a minimum of 10,000,000,000 and a maximum of 24,500,000,000 bbl. In 1915 Dr. Ralph Arnold[4] placed the original supply of oil at 9,098,557,000 bbl., of which he believed 5,763,100,000 bbl. remained in the ground at the end of 1914. The third estimate was made by the geologists of the oil and gas section of the Geological Survey for the use of the Secretary of the Interior in responding to a Senate resolution of Jan. 5, 1916, and was published in Senate Document 310, Sixty-fourth Congress, first session, Feb. 2, 1916. According to this estimate the reserve of oil available at the end of 1915 was 7,629,000,000 bbl. In the spring of 1917 the production records and the possible oil regions were closely reconsidered with marked conservatism by the same geologists, each studying the regions with which he had field acquaintance, with the result that the total oil available in the ground at that time was estimated at 6,182,000,000 bbl.

In the preparation of estimates by the U. S. Geological Survey consideration has been given to the general character of the geologic formations—stratigraphy, geologic history, structure—the number, thickness, continuity and pore space of sands, the curves of production, the gas pressure, the water relations, and the results of drilling in near-by or geologically similar regions. A large part of the producing or possibly productive area in the Western States has been examined and mapped by the oil and gas geologists of the Survey or is now under examination. Typical areas in the Central, Gulf and Eastern States have also been studied. Nevertheless, the criteria upon which estimates can be based vary in every degree of inadequacy in the different regions, and the quality of the results, therefore, varies with the extent and character of the data available and with the personal equation of the estimators. Necessarily the estimates for areas not yet tested, especially those remote from the producing fields, are based upon theoretical conditions, carefully considered. For most of the areas estimates were first formulated by the geologists who had studied the areas. Later, these estimates were discussed in conferences.

RECENT GEOLOGIC INVESTIGATIONS

Further recent geologic investigations in the field and the study of the results of testing and exploration, especially in the Rocky Mountain and Gulf States, have furnished the basis for a more reliable recalculation of the estimates for a number of the regions. The conclusion reached is that the available oil in the ground at the end of 1918 approximates 6,740,000,000 bbl.

The new estimates, combined according to the commercial fields, are given in the accompanying table, in which for comparison and information are shown the marketed production for 1917 and the estimated output for 1918, as compiled by John D. Northrop, of the Geological Survey, in charge of statistics of petroleum and natural gas, and the approximate total production of petroleum in the United States to the end of 1918, also based on Geological Survey records. For the immediate convenience of the reader there is also included the percentages of average gasoline recovery from the oils of the different fields at the present time. For the latter data the writer is indebted to Chester Naramore of the Bureau of Mines, in which bureau the returns of gasoline recovery from the oil runs are compiled. The general characteristics of the various crude oils in the different fields are too well known to require discussion in this paper, and their especial qualities will be fully considered in those to follow. It will, however, be noted that the reserves of the heavy oils of California and the Gulf coast are estimated at about 3,000,000,000 bbl. Probably such low-gasoline oils comprise more than one-half of the total reserves.

Those who have followed the history of petroleum in America and understand how much of our present-day oil-field development has taken place since Day made his estimates in 1908 and even since Arnold calculated the reserves in 1915 will appreciate the great advantages, mainly in the form of results of exploration and records of production, enjoyed by those who make computations now. However, with these circumstances in mind, we may, nevertheless, for comparison, compensate and bring to date the earlier estimates by deducting subsequent production to the end of 1918. The available oil in the

[1]Published by permission of the Director of the U. S. Geological Survey.

[2]Chief geologist, U. S. Geological Survey.

[3]U. S. Geological Survey Bulletin, No. 394, 1909, page 30.

[4]*Economic Geology*, vol. 10, No. 8, page 695, December, 1915.

ground at present would be according to these estimates, as follows:

Day (estimate in 1908), 5,402,000,000 to 19,902,000,000 bbl.

Arnold (estimate in 1915), 4,500,000,000 bbl.

Geological Survey (estimate in 1916), 6,647,000,000 bbl.

Geological survey (estimate in January, 1919), 6,740,000,000 bbl.

The recent estimate by the Geological Survey, as given above, and as differentiated by fields in the accompanying table, differs from that of 1916 mainly in a more conservative view as to prospects in Montana and recoveries along the Gulf coast and in a more optimistic attitude toward Kansas and the States of little or no present production. As compared with the very conservative estimate formulated in the Geological Survey in 1917 they represent greater confidence in Wyoming, north Texas and Alaska and several of the minor States. In general, they are to be regarded as conservative, and there is little probability that the actual yield will fall short of the calculated amounts. They are, however, likely to be again revised in the near future, as the modes of occurrence of oil and gas in different regions become more fully understood, as exploration proceeds, and as the areas offering possibilities of oil discoveries are examined more in detail.

AVAILABLE OIL REMAINING IN GROUND, AS ESTIMATED BY THE U. S. GEOLOGICAL SURVEY
(Bbl. of 42 gal.)

Oil fields	Marketed production in 1917	Marketed production in 1918 (preliminary estimate)	Total marketed production to end of 1918	Available oil left in ground, January, 1919	Present average gasoline extraction, per cent
Appalachian	24,932,205	25,300,000	1,221,737,000	550,000,000	28.0
Lima, Indiana	3,670,293	3,100,000	448,404,000	40,000,000	20.0
Illinois	15,776,860	13,300,000	298,159,000	175,000,000	22.0
Mid-Continent	144,043,596	139,600,000	990,573,000	1,725,000,000	24.0
North Texas	10,900,646	15,600,000	78,971,000	400,000,000	33.0
North Louisiana	8,561,963	13,000,000	90,902,000	100,000,000	28.0
Gulf	24,342,879	21,700,000	303,954,000	750,000,000	1.5
Wyoming	8,978,680	12,370,000	39,793,000	400,000,000	40-50
California	93,877,549	101,300,000	1,114,000,000	2,250,000,000	12.0
Alaska, Colorado, Michigan, Montana, etc.	230,930	230,000	10,651,000	350,000,000	....
Total	335,315,601	345,500,000	4,598,144,000	6,740,000,000	....

The reports of production of petroleum in the United States, as compiled by the Division of Mineral Resources of the Geological Survey, show that since 1858 approximately 4,598,000,000 bbl. of petroleum has been taken from the ground. This is more than two-thirds as much as the amount which, according to the latest estimate by the Geological Survey, remains available, and exceeds what would now be left according to Arnold. Further, the oil companies are now taking out over one-third of a billion barrels a year.

Relation of Production and Consumption

The situation as to petroleum production and the importance of the remaining oil resources of the United States are both graphically indicated by the curves in the accompanying chart. The most significant features here shown are the steep ascent of the consumption curve and the flattening, in 1918, of the curve of actual production in spite of the vigorous efforts of the oil companies to increase their war-time output even at the expense of their proved reserves. To fill the gap between our actual domestic production and the requirements of domestic consumption it has been necessary to reduce the oil in storage to the extent of 27,000,000 bbl. and to supplement this with a net importation of 31,000,000 bbl., chiefly from Mexico. The deficiency of our current production during 1918 has, therefore, amounted to 58,000,000 bbl., nearly half of which has been withdrawn from storage. That is to say, this country has to the extent of 27,000,000 bbl. of storage oil been "living on its hump," which is now reduced to about 123,000,000 bbl.

According to general expectations, barring disaster or shortage of supply, or much higher prices which might result from such shortage, the consumption curve is destined during the next year, and probably longer, to continue its present general trend beyond the 400,000,000-bbl. mark, which it nearly reached (397,000,000 bbl.) in 1918. On the other hand, whether the domestic production can be increased in volume to correspond to the consumption remains to be seen. Glenn pools and Cushings may await discovery, but the strike of a Glenn pool such as produced the bulge in the storage curve for 1907 and 1908, or of new Healdtons and Cushings, such as were largely responsible for the production swell of 1914-15, will make a less conspicuous wave in the greatly expanded and diffused production of today. Texas, the Osage country and Wyoming will furnish notable contributions, but so many fields are now running down that it will require numerous successive strikes of large magnitude to send the production curve so high that oil will go into storage without considerably increased importations. On the whole, even with prices stimulating the driller to greater efforts, it seems unlikely that the domestic production of petroleum can at best gain appreciably on the reasonably expected increase in consumption. It seems more probable that, unless consumption is restrained by high costs, the gap between consumption and production will continue to widen. In any event, this gap must be filled with oil from other sources. Further exhaustion of stocks in 1919 is a certainty that can be successfully minimized only by still larger importations.

The situation demands not only the prevention of waste, but the most economical and efficient use of our oil. Also, it warns operators to consider more thoughtfully and promptly the acquisition of foreign oil reserves. Mexico, to which the American public looks with optimistically hopeful eyes, probably contains less oil—perhaps very much less—than remains in the ground in the United States.

How long the commercial production of natural petroleum will continue in this country is a question whose answer is no less speculative than the quantitative estimates. After the production peak is passed, be it 1 yr. or 5, the annual output of natural oil will decline gradually for a long time. Oil wells will be producing at least 75 yr. hence. The pools cannot all be so soon discovered; the oil cannot immediately be got out of the ground. The discovery of deep sands is likely to give new life to many old or even abandoned fields. Pools will be found after prolonged search and repeated wildcatting in old as well as new regions, and this is probably especially true of the Gulf coast, where, unless geologic discovery and consequent new methods of search, come to the aid of the driller, it may be 75 yr. before some of the productive salt domes are revealed.

The most significant feature of the prospect, however, is the probability that, although an estimated two-thirds of our reserve is still in the ground, with an annual drain of one-third of a billion barrels, the peak of production will soon be passed—possibly within 3 yr. The date when the peak will be reached is a matter of individual opinion, in which predictions have wide range. There are many well-informed geologists and engineers who believe the peak in the production of natural petroleum in this country will be reached by 1921 and who present impressive evidence that it may come even before 1920.

Development of Oil Shale

In her deposits of oil shale the United States has an anchor to windward. Oil shale is a richly bituminous shale, some of it approaching cannel in character, interbedded, like coal, in series of shales, sandstones and limestones. The most extensive and valuable deposits known in America if not in the whole world are in northwestern Colorado, northeastern Utah, and southwestern Wyoming, mainly in what is known as the Uinta Basin. Rich beds of oil shale also occur in very limited areas in northeastern Nevada. Minor deposits, more conveniently located but for the most part leaner and less promising, are found in the Mississippi Valley and the Appalachian States. D. E. Winchester[8] and A. R. Schultz, of the Geological Survey, have estimated that there are in Colorado, Utah, Wyoming and Nevada deposits of oil shale in thicknesses of 3 ft. or more, and capable of yielding 25 gal. or more of oil per ton, sufficient to produce at least 75,000,000,000 bbl. of oil.

The oil is generated through the destructive distillation of the shale, and its character and composition depend largely on the processes employed. Rough dry or steam distillation tests produce distillates—essentially heavy petroleums—carrying both paraffin and asphalt with considerable nitrogen and yielding gasoline in an average of about 12 per cent. These rough tests indicate that the gasoline obtainable by distillation of these shales, even by simple methods, far exceeds in amount all the petroleum yet produced in the United States and may equal the remaining natural oil.

The production of oil from these shales is still in the experimental stage, in which various methods are being tested. Much doubtless depends on the processes devised and adopted. It is possible that initial commercial success may be determined as much by a study of methods and of the possible by-products and their values as by a further advance in oil prices. The technologic problems connected with the utilization of the oil shales are worthy of research by the best hydrocarbon engineers and chemists.

Shale oil is the most natural, satisfactory and ample substitute for petroleum, and it is likely to come into the market as the production curve of the natural oil glides downward beyond the peak, if not sooner. It must be borne in mind, however, that in spite of the probable very rapid growth of the shale-oil industry beginning with the day that shale oil is produced profitably on a commercial scale, it will require several years to construct and put into operation the enormous plants necessary to treat the millions of tons of shale which must be distilled in order to offset the waning production of natural oil, or fill a part of the gap between the production and consumption of petroleum in the United States.

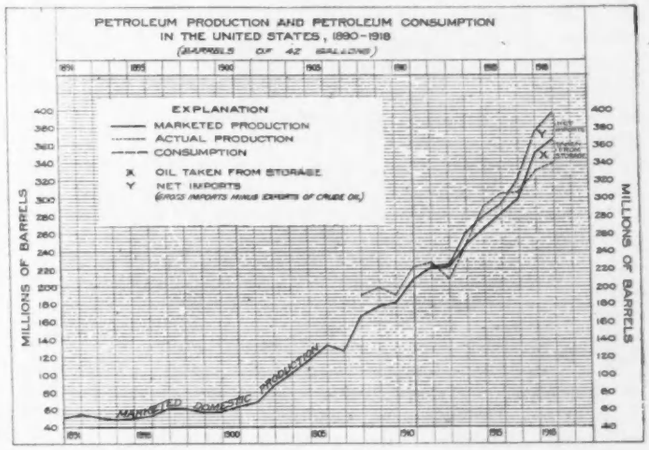


Chart Giving the Relations Between the Production and Consumption of Petroleum in the United States for the Past 29 Years

[8] U. S. Geological Survey Bulletin No. 641-F, 1917; Bulletin No. 691-B, 1918.

WHAT EVERY DISABLED SOLDIER AND SAILOR SHOULD KNOW

THE Government is resolved to do its best to restore every disabled soldier or sailor to health, strength and self-supporting activity, and strongly recommends that each man put himself in the care of the Federal Board for Vocational Education. Vocational experts will study his particular disability, advise him what course to pursue and give him training free of cost. In addition to this service, monthly compensation equal to the sum to which he is entitled under the War-Risk Insurance Act is given under certain conditions, to make it possible to follow a course of training. All disabled sailors and soldiers, whether in or out of hospitals, should write to the Federal Board for Vocational Education, Washington, D. C., for full information regarding the training courses and assistance offered.

Tractor Engine Governors

By G. L. MOYERS[1] (*Non-Member*)

MINNEAPOLIS SECTION PAPER *Illustrated with* PHOTOGRAPH

IN all classes of tractor design the necessity of engine governor equipment is generally conceded. The larger machines, with their heavy-duty, slow-speed engines, where high idling maximums are particularly destructive, require a governor to maintain the general integrity of the entire mechanism. The smaller types, or the so-called one-man tractors, while many of them are equipped with engines designed and built to operate successfully at relatively high speeds, must be equipped with governors to make practicable a system of one-man control. In plowing, conditions are continually encountered where the operator is engrossed with the steering of his machine and the management of his plows, to the exclusion of all else, in which cases throttle control must be automatically maintained. Moreover, only the very experienced and capable operator can approximate an efficient plowing speed under all soil and grade conditions, while the automatically controlled throttle can be depended upon to maintain a constant engine and plowing speed under all loads up to the power capacity of the engine.

The miscellaneous classes of belt work which the farm tractor must be designed to handle demand reliable throttle control, either manual or automatic. In this service the loads may be highly variable, ranging from an idle engine to a maximum with great frequency. Conditions are often encountered where manual control of the throttle is altogether inadequate. In any case, governor control will release the man at the throttle for productive labor.

A great majority of farm tractors are destined to do service under the direction of unskilled operators, and without the protection of an engine governor the tractor will surely render a costly account in burned-out bearings, broken parts and damaged machinery for the period of the driver's tuition. Irregular speed under changing load, racing of the idle engine, tardy opening of the throttle to meet a sudden demand for increased power, together with the always attendant overheating of the engine, breaking down of the lubrication medium and adverse effects on carburetion may be reduced to a safe minimum, if not altogether eliminated, by the use of an engine governor. The tractor manufacturer who anticipates a wide distribution of his product will use an engine governor for the protection of his machine in the hands of the tyro and for its more efficient performance and less arduous management in the service of the professional.

INFLUENCE OF MOTOR TRUCK UPON TRACTORS

Evidence is abundant that the ultimate tractor will reflect strongly the influence of motor-truck experience and practice. In its early conceptions the farm tractor gave promise of an individualized development. Its tendency, however, has been decidedly toward what has become accepted as conventional design, particularly with reference to the source and transmission of its power. Carried to its logical conclusion, this influence will dictate the general use of an engine governor in tractor design. The lessons and experiences incidental to the development of satisfactory governing instruments for motor-truck use are especially applicable to the governor problem of the tractor engineer. The troubles and difficulties of the two classes of service are mutual and common in character, the difference being one of degree only. What the motor truck has demanded of a governor the farm tractor demands with increased emphasis. A careful analysis of tractor requirements in the matter of governor equipment presents no distinctly new problems. The governor has as its primary purpose the maintenance of a constant speed throughout the torque range of the engine by mechanical connection with the engine throttle. The ideal governor would permit of an arbitrary speed setting of the engine running light, which speed would be absolutely maintained under an increasing load, and would finally fall only when the load exceeded the capacity of the engine at the governed speed. However, as we know them, all present governing devices become operative only with a loss of engine speed. Didactically, the ideal governor throttle opening would progress in a ratio with the increasing load rather than in a ratio with the diminishing engine speed. Granted that the former has not been achieved, our immediate purpose is to accept the latter and to make our governor operative from its closed to its wide-open position, confining the attendant loss in revolutions to as small a range as possible. Taking this as our proposition, let us consider its corollaries. A satisfactory tractor engine governor must have stability and staying qualities. It can be asserted that all units that enter the assembly of the successful tractor must subscribe to a new and higher standard of stamina. In the matter of governor design this attribute is perhaps the most difficult of incorporation. It is not sufficient that the tractor engine governor serve with the occasional assistance of a service station expert, because a great majority of the farm tractors will operate far removed from such a haven of refuge. The tractor's governor must go out prepared to stand on its own powers and be still on the job after months of abusive service have put the iron horse in for a general shakedown and overhauling.

The satisfactory engine governor must be compact, clean-cut and self-contained, not to a degree that the addition of an engine hood renders tolerable, but to an extent that makes protection of any kind unnecessary. It must function without personal attention of any kind on the part of the operator, either in the matter of adjustment or lubrication. If it requires lubrication, this must be automatically maintained in connection with the engine system. Finally, the occasional necessary repair or replacement of the governing unit should be so provided for in its design that it can be accomplished without difficulty by the operator himself, if necessary. To fill these requirements to the most satisfactory degree the tractor manufacturer may elect to use one of the few makes of governors that have proved themselves in service or may design one to meet some special requirements of his complete assembly. It is probable that most engineers will avail themselves of the experience

[1]Sales engineer, Monarch Governor Co., Detroit, Mich.

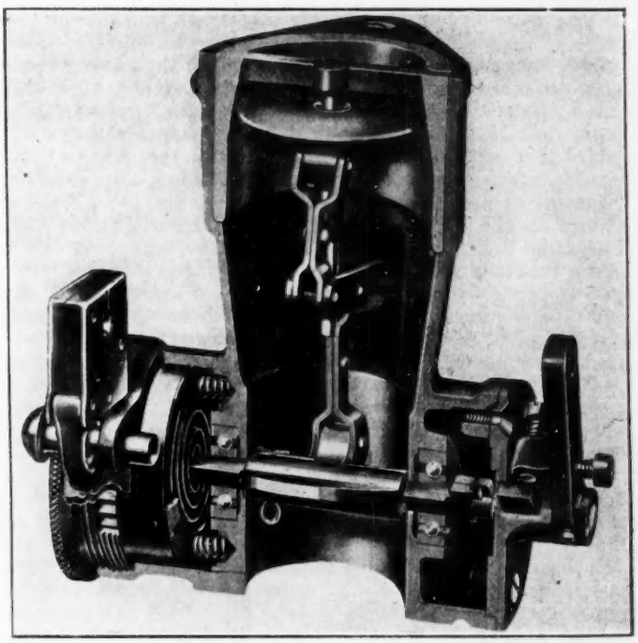
and manufacturing facilities of the firms which have specialized in governing devices.

The Centrifugal Type Governor

Two types of governors are popularly known and suggest themselves for tractor service: the centrifugal or flyball governor and the vacuum type. As applied to the tractor engine, we find the centrifugal governor in two forms: the built-in type, where the governor is in effect an integral part of the engine, housed either in the crankcase or with the timing gears and is operative through a throttle above the carbureter and a long control rod; or the bolted-on type, where the governor mechanism is contained in a separate housing and, together with the throttle which it operates, is inserted between the carbureter and the intake manifold. The built-in centrifugal governor is, without exception, incorporated in the general design of the engine. The engine builder, appreciating the definite relationship of the governor to the satisfactory performance and longevity of his product, provides a governing device whose parts are large and substantial and the mechanism of which is lubricated in connection with the engine system. Needless to say, such a governor is effectually housed and protected against accident and road dust, and its lubrication is assured to the same degree as that of the engine, requiring no individual attention in this respect. The system of linkage that is employed in such instruments between the governor mechanism and the throttle which it controls is, however, usually complicated, and the presence of several bushings and connections may in time cause a degree of wear that will result in a serious lag in the governor control. The inaccessibility of the built-in governor makes repairs difficult and complete replacement impossible without serious loss of time. When housed with the timing gears or in the crankcase breakage of the governor may cause irreparable damage to other engine parts. The bolted-on type of centrifugal governor offers several highly desirable features. Being in a unit with the throttle which it controls, the possibility of lag due to wear in the control linkage is eliminated. In case of accident or necessary repairs, the governor can be readily removed; and, if required, a service instrument installed with a minimum loss of time. In most instances it is satisfactorily housed and protected. It is necessary to provide a drive-shaft which is usually run off the timing gears. The extra set of gears and other connections which this arrangement demands, together with the flexible drive-shaft usually employed, represent a source of potential trouble, to be avoided assiduously if other alternatives can be considered. This type of governor is invariably provided with an individual means of lubrication, which, if it requires frequent personal attention, must be regarded as absolutely inadequate.

The Vacuum Type

The vacuum type of governor is an instrument designed and built to meet the conditions imposed by semi-high-speed engines in truck and tractor service. A radical departure from accepted practice and utilizing a different medium of power in its operation, it satisfies many of the conditions that are indifferently filled by the centrifugal governor. Externally, it consists of a compact brass body inserted between the carbureter and the intake manifold. This body completely houses all parts of the governor as there is no external drive. A vertical cross-section of the governor shows a modified cone at the top. Floating vertically in the cone, and guided by a metal pin centrally located, is a steel disk. At the bottom of the body is the governor throttle, mounted on bronze ball bearings. Between, and connecting the disk and the throttle, is a system of linkage arranged so that raising the disk closes the throttle and lowering the disk opens the throttle. A spring contained in the housing and attached to the end of the throttle shaft, operates at all times to keep the throttle in an open position with the disk at the lowest position in the cone. The governor is operated by the pressure of the gas passing through it. As the engine speed increases, the gas pressure against the disk also increases, until presently it balances the tension of the spring with the throttle in a partially closed position, and thus the engine is governed. When a load



A Vacuum Type of Governor Designed for Semi-High Speed Truck Adjusted for Maximum and Minimum Speeds

is encountered the engine speed will begin to fall, the manifold vacuum and the pressure against the disk are reduced and the spring pulls the throttle open, furnishing to the engine the gas required to handle the load. Thus the governor, under all conditions, tends to keep the engine speed constant.

In developing this instrument the characteristic governor problems have been encountered, although the absence of all driving and throttle connections has reduced their number. The tendency to hunt or surge, so general in mechanical types of governors, has been corrected. The matter of lubrication was finally settled by building an instrument that it is unnecessary to lubricate. It will be noted that there are no revolving parts in the governor. Motion of all parts is relatively slow and is oscillatory through an arc in no case greater than 80 deg. The general use of liberal size bronze bushings and, on the butterfly shaft, ball bearings with both the races and the balls of a special bronze alloy, insures a lasting and high degree of mechanical efficiency.

Universal adaptability to engines of different piston displacement is achieved through suitable changes in the characteristics of the governor cone. This unit is variable in all its inside dimensions and is changed ac-

cording to the bore and stroke and the number of cylinders of the engine, is volumetric efficiency and the speed at which it is to be governed. Speed adjustment through a range of approximately 200 r.p.m. is accessible through a single spring setting, which is effectually locked against unauthorized changes. In the matter of repairs or replacement, so vital in the choice of a unit for tractor equipment, the vacuum-type governor possesses distinctive advantages. Having no mechanical connection with the engine proper and being bolted only to the intake manifold and the carbureter, its removal and replacement can be accomplished in a few minutes.

ELECTRIC SHIP PROPULSION

CONSIDERABLE interest is being evinced at the present time in electric ship propulsion. The name is perhaps rather misleading, in that the electric plant is simply used as a flexible connection between the power generator and the propeller.

The flexibility of the electric system of transmission permits of an economy in the fuel consumption of ships over a wider range of power and speed than can be approached by any other system. Without the electric system undesirable complications are introduced into the main turbines, including the addition of separate suitably geared cruising turbines that come into operation only when the power and the speed have been reduced to a designed figure, thus giving an economy at reduced power which is, however, below that obtained by the electric system and even then does not afford the same flexibility as is achieved by the latter. It will be clear that this gain in economy over a wide range of power is of special advantage to a navy which must operate at a considerable distance from its bases, this being the condition for which the American Navy must provide.

Another advantage of the electric system for war purposes is the manner in which many of the important units can be accommodated in positions of great immunity from damage, especially from torpedo attack. This is a condition of maximum importance under war conditions, since with the electric system cables take the place of shafting, piping, etc., and can be well and easily protected. For war vessels of large power, especially where cruising economy and radius of action are of prime importance, the electric system of propulsion has therefore much to commend it.

Propulsion of Cargo Vessels

The foregoing remarks do not necessarily apply to the system when used for the propulsion of ordinary cargo vessels. The standard machinery for cargo carriers has been the triple-expansion steam engine and the Scotch cylindrical boiler. It is somewhat strange in the light of the great and extending application of the water-tube boiler ashore that it has made so little headway afloat in the mercantile marine. It has no economy over the Scotch boiler to offer; yet in weight, in quick steam-raising properties, good circulation and price it possesses many advantages with practically equal economy of fuel per unit of steam generated. The reason that the Scotch cylindrical boiler has held the field must be sought in its well-tried ability to deal with the great variations in quality of coal and of firing to which it is normally subjected. It is not a delicate boiler, as is well understood by those using it, and the large volume of water it contains gives a margin of safety from burning out or damage. Its long-continued use is simply a proof of the conservatism of marine engineers arising out of the necessary condition that reliability comes first and does not mean that the water-tube boiler, with coal-handling and firing appliances, will not be applied to mercantile marine use and that at an early date.

One condition to be satisfied in the past by marine engineers was that, if the worst conceivable mishap occurred, a repair, even a patch-up one, could be effected and the ship brought to port. The only exception was the losing of the propeller in a single-screw ship, without a spare one on board. This condition of easy repairs is admirably met by the Scotch cylindrical boiler and the reciprocating steam engine. The turbine has not yet been generally accepted for the propulsion of the average single-screw merchantman, although little doubt is entertained that in the near future the geared turbine installation will take a very prominent place in marine construction.

In spite of the opposition at the commencement of the application of mechanical gearing between the main engines and the propeller, the rate at which mechanical gearing has been accepted is remarkable, and, furthermore, double-reduction gearing is assured of an extensive and fair trial in the immediate future, although it cannot be said yet to have been really proved in practice. The turbine and gearing may be considered as the probable standard marine machinery of the near future, first of all for the larger twin-screw vessels and later for the single-screw average cargo carrier. This represents a very long step, although no one would be so bold as to state that the double mechanical gear represents finality in the solution of the problem of reconciling the turbine to the propeller.

Electric System Versus Geared Steam Turbines

To consider the claims of the electric system, it must be compared with the geared steam turbines expanding the steam in two or more turbines and utilizing the same amount of superheat. The question relative to superheat and superheaters afloat is not as simple as in land practice where they represent new standard practice. However, the superheater is gaining favor for ships and the difficulties relative to the astern turbine and superheat are in no way incapable of solution. The electric system has the advantage that the astern turbine is eliminated and the main generators are kept running continuously in the one direction, so that the question of superheat is not fraught with the same difficulties. Elimination of the astern turbine, except insofar as superheat is concerned, is not such an advantage as has been made out by advocates of the electric and other similar systems.

The electric system will therefore have to be compared with the double-reduction geared turbine in respect to (1) first cost, (2) economy of operation in regard to fuel costs, (3) personnel, (4) reliability under sea-going conditions and the facility with which repairs can be effected and (5) weight and space occupied.

In regard to first cost, little can at present be said, as the system is new and a small saving in fuel would cover a relatively large difference in capital charges, although the electric system with its extra conversion of energy and the cost of copper for cables, etc., would seem to be intrinsically expensive.

As regards economy of operation at sea, qualities of coal, which vary from port to port and the suitability of the firing, which is an uncertain factor, make comparison difficult. With the electric system, until such time as marine engineers shall have been trained to a higher degree of proficiency in electrical matters questions of personnel are bound to militate against its employment, and while electrical machinery has reached a great degree of reliability, yet its application to marine purposes must be very carefully studied lest certain conditions should not be satisfied. Of course the question of repairs is always in favor of the simplest of all systems, and this cannot be said to be the electric system.

There are now several double-reduction geared ships in operation and others are being completed, so that we may hope at an early date to have such data as will enable a comparison to be made between the two systems on the lines suggested. —*Engineering* (London).

APRIL COUNCIL MEETING

THE meeting of the Council held on April 12 was attended by President Charles M. Manly, First Vice-president B. B. Bachman, Second Vice-presidents J. J. Amory and L. S. Keilholtz, and Councilors David Beecroft and J. V. Whitbeck.

Considerable time was spent in consideration of the time and place of the Semi-annual Meeting of the Society to be held this year, as well as the formulation of a program of most value to the members. The action taken is indicated by the notice given in this issue of THE JOURNAL of the Summer Meeting to be held June 23 to 27 at Ottawa Beach, Mich.

An interesting communication regarding the holding of a meeting of American and European engineers interested in heavy fuel engines in this country was taken up. The Council favored the holding, at a time to be decided upon later, of an international convention of Diesel and oil engineers. A meeting of this kind will probably be held as soon as it is possible to arrange it, under the joint auspices of American engineering societies particularly interested.

Plans are under way for the holding of a meeting of the Society at the time of the tractor demonstrations to be given at Wichita, Kan., about the middle of July. This meeting will be similar to those held by the Society at previous tractor demonstrations in the farm belt, as at Fremont and Salina.

The Mid-West Section of the Society has been requested to cooperate in arranging for the conduct of a technical session of the Society in connection with the meeting of the National Gas Engine Association to be held at Chicago June 2 and 3.

The Council approved 118 applications for membership in the Society. These included applications for individual membership and for affiliate membership, there being two of the latter. In addition, one application for student enrollment was granted.

Owing to war conditions, the Council has not been accepting for some time applications from men not citizens of this country or of countries with which we have been associated during the war. Hereafter applications for membership will be received from all except those who are citizens of enemy countries.

The Council considered in detail the items of work that have been before the various Divisions of the Standards Committee, as well as a number of new subjects that have been proposed. A list of current work for the Divisions was decided upon, as shown elsewhere in this issue of THE JOURNAL. A few of the Divisions remain to be reorganized as to both personnel and work. In the assignment of subjects to the Standards Committee, the formulation of probable and possible international standards has been borne in mind.

The Council voted to discontinue for the present the Fuel and Lubricants, the Foreign Cooperation, and the Data Sheet Divisions. The first Division has been supplanted by the Research Committee recently appointed by the Society, its prime problem consisting of matters involved in the present fuel situation. Chairman Bachman of the Standards Committee is the Chairman of this committee. A Foreign Relations Committee, collateral with and not subsidiary to the Standards Committee, will hereafter handle in a broad way, at least, questions of international standardization. With regard to the Data Sheet Division, the work formerly carried on by it will be conducted directly from the office of the Society in conjunction with specialists as particular cases may require.

The following appointments to the Standards Committee were made, with assignments as indicated: W. C. Berling, Electrical Equipment Division; C. E. Wilson, Electrical Equipment Divison; J. B. Fisher, Engine Division; A. W. Scarratt, Iron and Steel Division; R. A. Townsend, Iron and Steel Division; E. L. French, Iron and Steel Division; W. F. Graham, Iron and Steel Division; C. A. Criqui, Iron and Steel Division; H. F. Wood, Iron and Steel Division; W. R. Strickland, Miscellaneous Division; M. W. H. Wilson, Shaft Fittings Division; G. W. Carlson, Shaft Fittings Division; A. M. Dudley, Stationary Engine and Farm Lighting Division; P. M. Heldt, Stationary Engine and Farm Lighting Division; W. G. Wall, Transmission Division; S. O. White, Transmission Division; H. D. Church, Truck Standards Division; A. F. Masury, Truck Standards Division; F. G. Alborn, Truck Standards Division.

The rules governing the work of the Standards Committee were revised. These are printed elsewhere in this issue of THE JOURNAL.

The next meeting of the Council will be held at New York City, Monday, May 19.

THE DIESEL ENGINE APPLIED TO TRAIN HAULAGE

AN interesting application of the Diesel engine was made by Sulzer Bros., Winterthur, Switzerland, in 1913. This was the use of that type of engine for driving what is known as a thermo-locomotive, but details have not been available on account of the war. The application was not made until the reversing capacity of the Diesel type of marine engine had been perfected so that it was not inferior to the steam engine from the viewpoints of speed and safety. In this application, however, the problem of starting, that is, the development of maximum tractive effort while the locomotive is standing still, caused trouble, and the entire construction in relation to the other parts of the unit had to be adapted to meet these peculiar conditions. Compressed air was employed to start the locomotive, and as soon as a speed of approximately 10 km. was reached, fuel was admitted to the engine. Efficiency trials were made by the Prusso-Hessian State Railway Administration, but the breaking out of the war interfered with their completion. If the working capacity of the locomotive and its economy are proved after subsequent trials, it will be taken over by the Railway Administration.—*Technical Supplement to the Daily Review of the Foreign Press* (London).

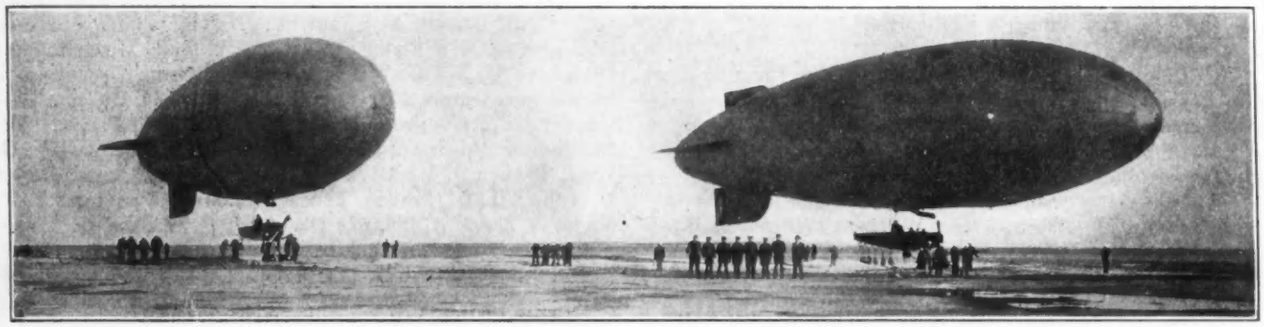
Operations of Naval Aircraft

By COMMANDER J. H. TOWERS[1] (*Non-Member*)

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

THE purpose of this talk on the operations of Naval aircraft is to give a general idea of what this part of the Navy accomplished during hostilities and what may be expected from it in the near future. To make the subject entirely clear it will be necessary to give a few statistics, but in general such details will be avoided. I should add that the operations of the Marine Section and of certain Coast Guard personnel are included in this account.

At the declaration of war the Navy had only one aircraft station, twenty-two training seaplanes, and a total of thirty-eight aviators. It had no seaplanes fit for service use. Its so-called lighter-than-air equipment was negligible. It was, of course, realized that Naval aircraft would be required, but when, where and in what quantity, nobody could say. The proposed Army aviation program was at this time overshadowing everything else, and very few people realized that the Navy would have to embark on a schedule in any way comparable with that program. Additional orders were placed for training seaplanes and lighter-than-air craft. Additional flying schools were opened, and enrollment in the Naval Reserve Flying Corps was really begun. A special board of officers was sent abroad to study foreign types, and about this time the French Navy requested the sending of a detail of trained and student aviators to France for further instruction, to assist eventually in combating the submarine along the French coast. It is interesting to note that this detail of Naval aviators was the first organized American force to land on French soil.



TWO OF THE NAVAL AIRSHIPS READY FOR FLIGHT

ADOPTION OF NAVAL AIRCRAFT PROGRAM

When the board returned from abroad, with even more startling facts than we had theretofore had regarding the submarine menace and the efficacy of aircraft in dealing with it, it became obvious that we must not only put over aircraft of a type far superior to any we then had in the Navy but also get them out in what at that time appeared to be astounding quantity. After what might be termed a heartbreaking session, lasting late into the night, a definite program of types was decided upon, and that program was adhered to through many periods of doubt and criticism. This adherence resulted in uninterrupted production, and the performance of the aircraft vindicated those who were responsible for the selection of the types.

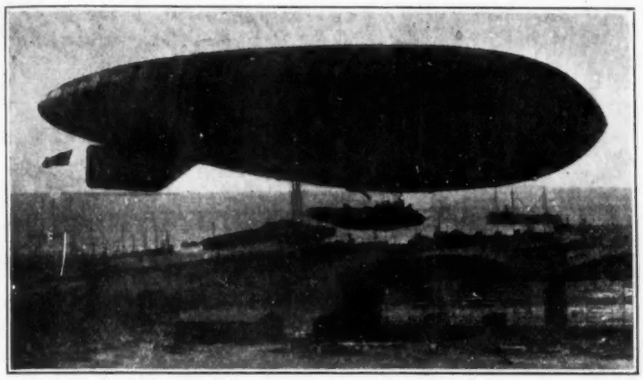
From this time on the situation developed rapidly, and by late summer the Navy was embarked on an astonishingly large aviation program on both sides of the Atlantic. When the armistice was signed there were in operation twenty-eight U. S. Naval Air Stations abroad, thirteen in the United States and insular possessions and two in Canada and twelve land squadrons for special offensive operations against submarines at their bases to say nothing of the numerous schools, storehouses, assembly plants, repair depots and the aircraft factory, etc., required to furnish the necessary facilities for the operation of these stations. The total aviation personnel numbered over 42,000, a figure nearly as large as the total personnel of the entire Navy at the outbreak of the war. Our problems of supply were very difficult, as the primary function of the stations, which was the "strafing" of submarines and the protection of shipping, necessitated the location of stations at strategic points, regardless of communications. These locations abroad extended from the northern end of Ireland to the southern part of Italy, not to mention the Azores. Eight were located on islands offshore, necessitating considerable special water transportation. Very few were in settled communities; hence they were compelled to be completely self-sustaining.

Little has been published as to the nature and extent of Naval aircraft operations during hostilities. As I stated before, our primary mission was the destruction of the enemy submarine, wherever it could be found, and second only to this was the protection of supply and troop ships. The primary mission was purely offensive, and its execution, rather varied in form, was as follows:

Routine overseas patrols
Emergency or S.O.S. patrols
Bombing submarines in their bases

Seaplanes of large cruising radius and airships were

[1]Office of Naval Operations, Navy Department, Washington.



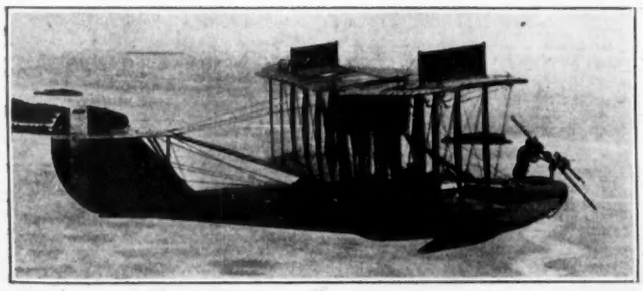
THE NAVY DIRIGIBLE C-1 ARRIVING AT KEY WEST UPON THE COMPLETION OF ITS FLIGHT FROM ROCKAWAY BEACH, N. Y.

used for routine patrol. Each station had a zone assigned to it and covered that zone as thoroughly as possible from daylight to dark. The patrol routes were so laid out that the greatest area was covered with the least possible mileage, and each seaplane traversed courses which were carefully laid down in the flight instructions to the pilot. These aircraft were armed with bombs of either 230 or 500 lb. and also with machine guns for use against the submarine crews encountered on the surface or against hostile aircraft. The seaplanes would stay out from 4 to 9 hr., depending on the distance they had to cover, and the airships sometimes stayed out over 40 hr. In some cases these patrols took the seaplanes near islands where rest or refueling stations were provided, as at Bimini in the Bahamas. The erection of these auxiliary stations resulted in practically doubling the extent of operations in these localities.

A TYPICAL DAY'S WORK

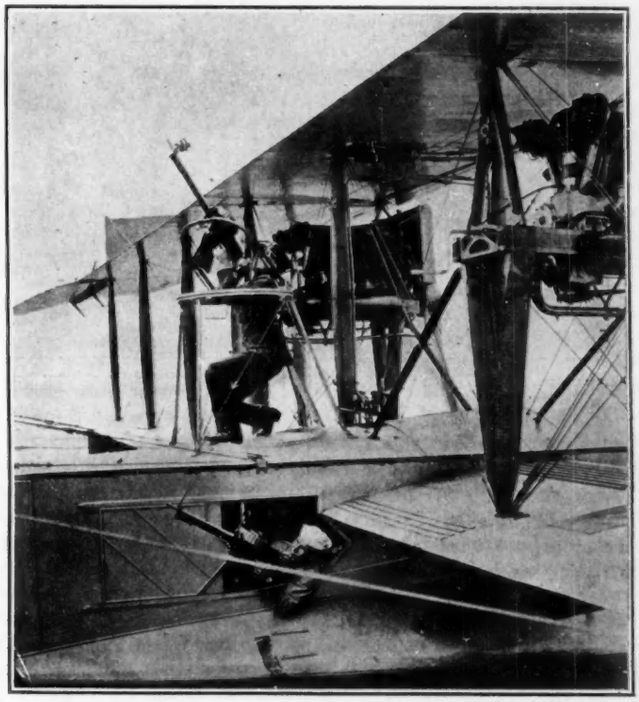
Following is a sample of a pilot's log for one day, March 15, 1918:

Called at 4 a. m. for inner patrol in H-12 No. 4545
5:30 Left water—dark
6:10 Sighted Kentish Knock Light Vessel
6:40 Sunrise
7:10 Sighted torpedoed British destroyer F-90 being towed toward Harwich by torpedo boat destroyer F-31
7:10-7:30 Searched area
8:15 Shipwah Light Vessel
8:25 Sighted two Hun mines—sank them both—machine-gun fire. Reported their position to base by wireless telegraph
8:40 Six trawlers sweeping
9:00 Sunk Light Vessel
9:20 Landed



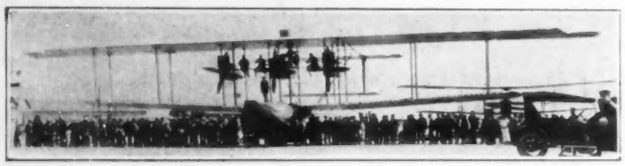
THE H TYPE NAVY FLYING BOAT EQUIPPED WITH A DAVIS GUN IN THE AIR

2:00 p. m. Three machines left water—No. 4280, Capt. Gordon—4285, Capt. Webster—4290, Ensign Hawkins
3:10 Sighted Dutch coast (Hook of Holland)
4:15 Sighted two two-seater Hun seaplanes
4:15-4:35 Dropped bombs and chased hostile aircraft
4:35 Shot down rear Hun in flames—the other got away into the clouds
4:45 Turned west
4:50 No. 4280 (Capt. Gordon) came down, engine trouble—landed O.K. in 6-ft. swells
4:50-5:05 Circled around No. 4280
5:05 No. 4280 took off O.K.—carried on west
5:35 Sighted large Hun mine-laying submarine 4 miles off port bow fully blown on surface. Opened out for him. Fired recognition signals—no answer. He got under just before we reached him. We had only Lewis guns, as had dropped bombs
6:10 Sighted North Hinder Light Vessel
7:00 Sighted coast—Orfordness
7:20 Landed Felixstowe—dark
Total flying time for day, 9 hr. 10 min. in air



GUN MOUNTS ON A NAVY AIRCRAFT

The emergency or S. O. S. patrol was made only when a submarine was reported as being in the zone covered by the station, a limited number of seaplanes being held in reserve for such an emergency. Successful accomplishment of a mission depended almost entirely on the rapidity with which fully-equipped planes could be got off with complete written instructions as to the supposed location of the submarine, total area to be searched, etc. On surprise inspection of the northern stations in the United States, shortly before the armistice, emergency patrols were ordered out immediately upon the arrival of the inspection board, and although orders were entirely unexpected, it was found that the longest time required by any of the stations to get out orders, get two HS-1 type planes launched, completely equipped and manned and in the air, with full instructions, was 7 min.



THE NC-1 SEAPLANE

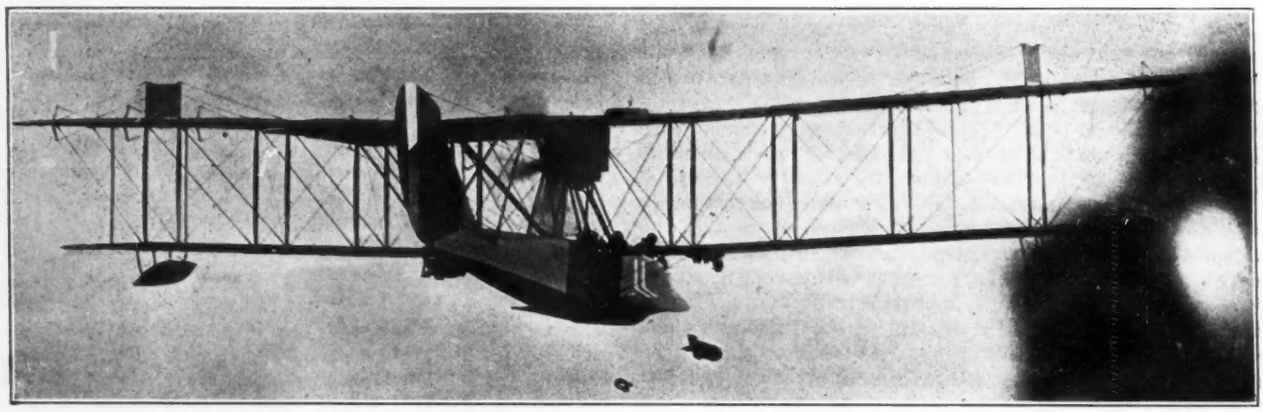
This shows the facility with which seaplanes can be operated compared with surface craft.

During the late winter of 1917-18 and early spring of 1918 it was noticed that the aircraft operations were becoming so effective that submarines were more or less consistently avoiding the areas which could be covered by aircraft from the various stations of the Allies and the United States and were extending their operations much farther out to sea. They were able to do this because of the increased radius of action of the larger submarines. Of course, their chances of getting ships were reduced, as they were not within the cone-shaped area through which all ships making for or departing from a port would have to pass, but, on the other hand, if they sighted an unarmed ship without escort, they were so far from the bases that they could sink it before destroyers or other vessels from shore bases could render assistance. It was therefore decided that the proper plan was to attack the submarines in their bases wherever such bases could be reached.

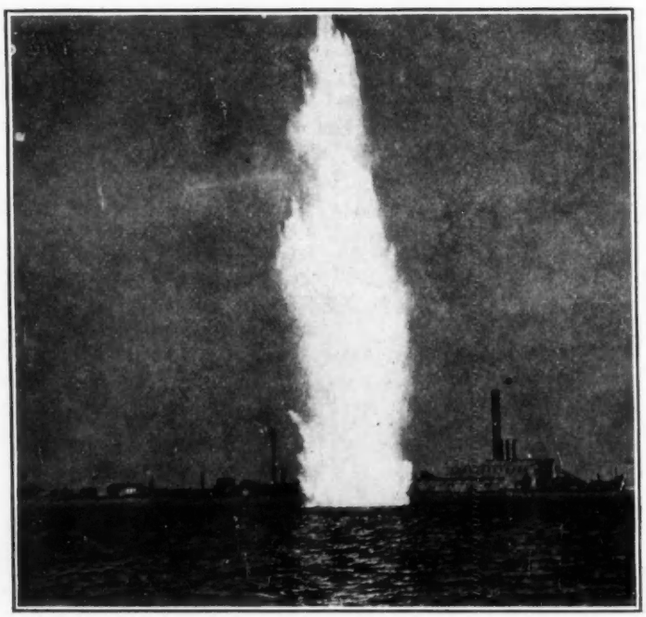
The so-called Northern Naval Bombing Group, consisting of six squadrons of land day-bombing airplanes and six squadrons of land night-bombing airplanes, with complete equipment, was organized to take on this job. The personnel of this organization was partly naval and partly marine. To put this organization in the field required a very speedy modification of training plans, and great assistance from the Army in the supply of material. A land training school of considerable size was got under way by the marines, night flying training was instituted at Pensacola, Fla. and a large number of pilots were sent to British schools and service squadrons. Although the cessation of hostilities came before this Northern Bombing Group got into full swing, it accomplished a considerable amount of good work and would undoubtedly have been a decidedly sharp thorn in the sides of German submarine warfare. Various other offensive plans were under way, and a large number of experiments for the purpose of developing new uses for aircraft were being carried on. Since these did not appear in the field they must necessarily be kept secret, at least for the time being.

ESCORTING CONVOYS

The secondary function of seaplane patrol related to the escort of convoys. The very large overseas transportation of troops and supplies required that all possible protection be afforded, and aircraft, especially airships and kite balloons, were used most extensively in this work. Convoys were escorted out of the United States ports to distances which could be considered comparatively safe and were met outside European ports and escorted in. That so few troopships were torpedoed can be credited, to a considerable extent, to the arduous work of the aircraft. This work did not offer the excitement and interest of flying at the Front, or even of the offensive sea patrols, and the officers and men who did it, day after day, summer and winter, deserve a great deal of praise. And yet convoy escort was not wholly monotonous or devoid of interest; witness the case of an American seaplane operating off the French coast:



BOMB BEING DROPPED BY A NAVY FLYING BOAT



COLUMN OF WATER THROWN UP BY AN EXPLODING DEPTH BOMB

On April 23, 1918, while on morning patrol with a convoy of twenty-six American vessels, the observer discovered an enemy submarine awash and steering for the convoy. Two minutes later she submerged, only to reappear close to one of the vessels. The seaplane maneuvered directly over the undersea boat and dropped one bomb, scoring a direct hit close to the conning tower. At this time the top of the conning tower was showing about 2 ft. above the surface. Wreckage strewed the water, and sufficient was gathered up by trawlers later to determine the type of the destroyed submarine. While destruction of enemy submarines by U. S. seaplanes was far from being the usual thing, it can positively be stated that this was by no means the only instance of its kind.

During the latter part of the hostilities certain of our dreadnaughts in the war were equipped with fast planes for spotting, fighting and reconnaisance. The inactivity of the German fleet did not give any opportunity for a demonstration under battle conditions of the usefulness of these aircraft. There is no doubt, however, as to the increased necessity of having the fleet, especially the scouting forces, amply equipped with airplanes.

As has been stated, the primary mission of Naval aviation during hostilities was waging war against the submarines, and this naturally resulted in a rather one-sided development. We now have an opportunity, however, to look into the future and consider what lines of development will be most needed to make aviation an efficient and well-balanced arm of the Navy, and particularly of the great fighting force, the fleet.

Future Development

I believe that Naval aviation development for the next few years will be along the following lines:

(1) Small airplanes or seaplanes for use from fighting ships for spotting, short distance reconnaisance and fighting
(2) Medium-sized airplanes or seaplanes for use from large high-speed ships with "flying-off" decks or special launching and recovering arrangements, for medium-distance reconnaisance, torpedo carrying and bomb dropping
(3) Kite balloons, and possibly airships, capable of being towed, to be carried by scouts and capital ships for spotting and reconnaisance purposes
(4) Large seaplanes and airships to be based on shore for operations with the fleet and for operations as an independent Naval force when needed

Under the first class the sizes are necessarily limited by the fact that they must operate from a fighting ship and not interfere with the primary function of that ship. Land-type airplanes are easier to launch, and have better fighting qualities, but on the other hand they must either return to shore or to a ship with flying-off deck, or land in the sea, with almost certain damage. Will their usefulness offset these disadvantages? That remains to be seen.

Under the second class, that of medium-sized aircraft for use from special ships, the question again arises, shall they be airplanes or seaplanes? There is no doubt about their being able to fly from and land on the decks of special ships under reasonably good conditions, but in cases of engine failure we again have the airplane in the water. The launching of seaplanes by catapult has been developed to a satisfactory point, and several methods of recovering the seaplanes without stopping the ship have been suggested. Some of these methods have considerable merit, but require a vast amount of experimentation. Airplanes of the types desired are already in existence. The seaplane characteristics will be affected largely by the method of recovery to be used. I think it probable that a 300-hp. type will be selected.

Under the third class, those operating from shore bases, come the big seaplanes and the medium and big airships. The limit to the size of the seaplane is an engineering matter; what is wanted for operation is seaworthiness and long radius of action. I have no doubt that in a few years this type will be of several thousand horsepower, and it may have a steam powerplant. These seaplanes will compete with destroyers. They naturally have the advantage of speed and vision, but must also be able to navigate accurately for long distances out of sight of all fixed marks, to land in and rise from fairly rough water to exercise right of search and must be so reliable and self-sustaining that they return to shore bases only as a destroyer returns—for rest, refueling and overhauls to machinery. Until this stage is reached they will be looked upon as nuisances, necessary, perhaps, but undesirable, especially if they make continued calls on surface craft for help.

The rigid airship in its present stage of development has the advantage over the seaplane for long-distance work over the seas. The performance of rigid airships during the last 2 yr. has been marvelous. They are bound to be one of the most important aids of a fleet. I believe that in a few years it will be considered as foolish for a commander-in-chief to proceed far to sea in time of war without rigid airships well out ahead of his first line of scouts as it would now be considered for him to go out without scouts. Again, however, these airships must be capable of taking care of themselves. The successful production of argon has removed their greatest handicap, which has been vulnerability, but they still require nursing when they are on shore. At the present time, the shed on shore to house the airship costs almost as much as the ship itself, and the ship can be taken in and out only in good weather and with the aid of hundreds of men. They must be so built that they can moor, as a ship anchors, and ride to that mooring, good weather and bad. Then we can have mooring masts all along the coast and in the insular possessions and sheds only at repair stations to be used for overhauling as the drydock is for a ship.

It is obvious that America has gone far in the past 18 months in the development of aircraft, but when the specifications outlined for proper military performance are considered it is equally obvious that there is still a long distance to go. Reliability of powerplants is, after all, the prime requisite, and it is principally to the automotive engineers that we look for assistance in obtaining such reliability that the pilot can forget about his engine once he takes the air.

Status of Refinery Practice with Regard to Gasoline Production[1]

By E. W. Dean[2] (*Member*)

Annual Meeting Paper

As one of a series of papers discussing future prospects for a supply of internal-combustion engine fuel, the Bureau of Mines has been asked to present information relative to the efficiency of present-day petroleum refinery practice. The Bureau is sufficiently acquainted with this subject to realize the inadequacy of the data upon which discussion must be based. The figures given are actually nothing more pretentious than a series of rough estimates, and any constructive criticism that may be offered regarding them will be welcomed.

Possibilities of Advance in Refinery Practice

The several most important ways in which the petroleum refining industry can increase the output of gasoline from a given quantity of crude oil may be listed as follows[3]:

(1) Universal adoption of a high "end-point" or upper volatility limit for gasoline
(2) General use of more efficient distillation methods and equipment
(3) Recovery of gasoline now lost in refinery operations
(4) Wider use of cracking processes

There are considerable differences in the grades of gasoline marketed throughout the country by different refineries and sometimes at different times by the same refinery. A notable point of variation is the upper volatility limit, or end-point. In the days when gasoline was simply a by-product of the refining industry, the end-point figure was approximately 150 deg. cent. (302 deg. fahr.). This type of gasoline is now practically extinct, and the so-called "high-test" engine fuel now marketed in relatively small quantities has an end-point of approximately 175 deg. cent. (347 deg. fahr.). The usual grades of gasoline are represented by end-point figures between the limits of 200 deg. cent. (392 deg. fahr.) and 230 deg. cent. (446 deg. fahr.).

The fact that gasoline of as high end-point as 230 deg. cent. (446 deg. fahr.) is being used in tremendous quantity and with satisfactory results renders it desirable to consider the possible increase in engine fuel supply if this upper volatility limit were universally maintained. The Bureau cannot go on record at present as either advocating or opposing such a standard, but is simply discussing what might be accomplished in the way of increased gasoline production if it were adopted. The present estimate, based on miscellaneous data at hand, is that from 15 to 20 per cent more gasoline would be available if a universal end-point equivalent to that of the "heaviest" grade at present marketed in quantity should be maintained.[4]

The possibility of such a standard is, incidentally, dependent upon either a considerably increased production of casinghead gasoline or the development of engines that can utilize liquid fuel having smaller properties of volatile constituents than the types now marketed. The high end-point gasoline now marketed is almost invariably of the blended casinghead type.

The distillation methods employed by petroleum refineries do not operate with the same degree of efficiency that is attained in some other industries. Certain percentages of hydrocarbons boiling below the accepted upper temperature limit for gasoline are always present in kerosene or fuel oil. This does not necessarily discredit the technical ability of refiners, many of whom are maintaining as high a degree of distillation efficiency as is profitable under present commercial conditions. There is no doubt, however, as to the possibility of augmenting the gasoline supply through an increase in the average distillation efficiency of refineries, and it is important to estimate the order of magnitude of the probable gain.

Here again exact data are lacking, and reliance has been placed on miscellaneous indirect evidence. The probability seems to be that efficiency in gasoline recovery varies in different refineries between the limits of 75 and 95 per cent. The latter figure is probably about the maximum that can be economically attained, and the average is undoubtedly not lower than half way between the limits. It is, therefore, improbable that the Nation's supply of gasoline will be increased more than about 10 per cent through advances in the technique of large scale petroleum distillation.

Recovery of Gasoline Lost at Present

Bureau of Mines refinery statistics for 1917 and for the first seven months of 1918[5] show that an average of about 4 per cent of the crude oil treated was lost in the course of refinery operations. Part of this loss was, of course, inevitable, but part represented gasoline that escaped with refinery gases. Recovery of this gasoline could have been effected by the use of methods and equipment similar to those employed for the production of casinghead gasoline. Such processes are already successfully operating, and there is no reason to doubt that the extraction of gasoline from refinery gases will eventually become a general practice.

Assuming that half of refinery losses are preventable

[1]Published by permission of the Director of the Bureau of Mines.

[2]Petroleum chemist, Bureau of Mines Experiment Station, Pittsburgh, Pa.

[3]One other possibility might be mentioned; the refining of crude petroleum now marketed as fuel oil without removing its naphtha content. The Bureau has not, however, succeeded in uncovering statistical evidence indicating that developments in this line could augment production by a maximum of more than 3 to 5 per cent of the quantity of gasoline now refined.

[4]In this connection it is interesting to note the probable increase that would result if the end-point universally adopted were sufficiently high to include the fractions of petroleum now marketed as kerosene. Bureau of Mines refinery statistics for the calendar year 1917 show that about 20 per cent of the crude petroleum refined was marketed as gasoline, and about 11 per cent as kerosene. If, therefore, the end-point selected were high enough to include both of these fractions, instead of stopping with a figure representative of the "heavy" engine gasolines of today, the resulting increase in supply would be 55 per cent, instead of 15 to 20 per cent. Wherefore, it appears that even the long-sought kerosene consuming engine is not going to keep the automotive industry on "easy street" for many years.

[5]Senate Document No. 280, Sixty-fifth Congress, second session. Letter from the Director of the Bureau of Mines, entitled "Production of Crude Oil." Sept. 24, 1918.

in this way, it appears that gasoline amounting to about 2 per cent of the crude oil refined and about 10 per cent of the gasoline produced could be added to the supply of motor fuel.

The wider use of cracking processes is without doubt the most promising means by which refiners can increase their output of gasoline from a given amount of crude petroleum.

In a paper presented before this Society about a year ago,[6] the author ventured to state an opinion to the effect that, if cracking processes were employed to the full extent of their applicability, the total production of gasoline from the quantity of crude oil now produced might be doubled. This statement is one that indicates considerable optimism for the future of the cracking art, and the Bureau has been agreeably surprised at its failure to arouse controversy. To prevent any future misinterpretation, it is perhaps best to make clear the fact that this statement implies a possibility, the commercial feasibility of which is yet to be demonstrated.

The future of cracking processes may be affected by the development of unfavorable conditions of various sorts. Two in particular deserve mention in the present connection.

Up to date, the development of the art of cracking has been far from complete, in spite of the considerable attention that has been given to this line of technical operation. Only one process, that of Burton, is today a real commercial factor in the production of motor fuel, and this is representative of a type that seems to involve certain inherent limitations in applicability. If the cracking reaction is to be applied to the extent necessary for a doubled gasoline production, other types of processes must be put into successful commercial operation, or the present apparent limitations of the class in which the Burton process belongs must be obviated. The Bureau of Mines is optimistic regarding the future commercial success of several other processes, but believes it is only fair to state that such success is not known to have been attained, as yet, in any large measure.

A second development that may restrict cracking operations is the existence of an unfavorable ratio between the market prices of gasoline and fuel oil. The production of cracked gasoline necessitates the consumption of fuel oil, and, if the demand for the latter commodity exceeds the supply, its price is bound to rise and the margin of profit on cracking processes wiped out. It is an open question whether or not the consumption of fuel oil can ever be reduced sufficiently to permit doubling the production of gasoline by the use of cracking processes. The Bureau of Mines cannot venture any prediction in this line, except that the price of gasoline is likely to exceed the present level before cracking processes will be employed to the extent indicated.

Summary

The estimates included in the present series apparently indicate that the refiner may be able to augment his production of gasoline from a given amount of crude petroleum by from 35 to 40 per cent, exclusive of the gains possible through wider application of the cracking reaction. Some of the possibilities, however, overlap each other, and a more probable summation estimate is 25 to 30 per cent. The Bureau believes that, if commercial developments are favorable, the wider use of cracking processes may permit of further increases up to a possible additional 100 per cent. No prediction, however, is ventured as to what part of this figure will actually be attained.

It may be mentioned, also, that the development of engines capable of utilizing the combined gasoline and kerosene fractions of crude petroleum would not be likely to alter the limit of maximum increase, but would materially hasten the day when it would be attained, and would, in considerable degree, help to keep the price of liquid fuel from ascending to painfully high altitudes.

The present paper may have produced the impression that the Bureau of Mines is not enthusiastic over the advantages to be gained by the development of a kerosene-consuming internal-combustion engine. Such is not the case, but it must be emphasized that this is not the only line along which the automotive industry must work.

In preparing this paper, the author has made very extensive use of statistical information collected by H. F. Mason of the Bureau of Mines. The evidence upon which estimates are based has been reviewed with H. H. Hill, J. P. Smootz and E. E. Lyder of the chemical staff of the Bureau of Mines, Petroleum Division, and the figures given have been agreed upon as most probable.

The Discussion

HUGO C. GIBSON:—The paramount thought expressed by all authorities on this vexed subject is that we cannot have the easily vaporized engine fuel; that we must be content with the higher boiling point, and that it is "up to" the engine. I agree with this and believe that the solution which will avoid too sudden a change and partial disorganization of the automobile business is to educate the public to modify their demand for a vehicle that will do sleight-of-hand tricks in getting under way at the touch of a button and will require no attention under extreme atmospheric changes of temperature; to educate them to be as economical of their fuel as the public of other countries not so blessed as this in the ownership of the actual source of supply of their fuel; to make them realize that specific devices must be employed to overcome the difficult problem now facing them, and that the application of these devices to automobiles will necessarily increase the prime cost of the vehicle, but that it will reduce the high future cost of pleasure motoring and of food and merchandise produced or transported by motor vehicles; to educate them to realize that they are today discarding, wasting, a large proportion of these natural resources and that with the cooperation of the automotive manufacturer the wastage will be saved.

At present the public blames the refiner for the poor gasoline, whereas it is not the fault of the refinery or its product that we break up our engines and deplete our pocketbooks any more than it is the fault of the kitchen that we break a tooth and damage our digestion on the pearl concealed within the oyster. The pearl is there by beneficence of nature and force of circumstances. It is our fault if we do not recognize the pearl and place it in an appropriate setting so that it may become of maximum value. The advantages of economy in the refinery will accrue, but these economies are, while essential, of somewhat minor importance in comparison with the wanton waste of the mickle per engine which makes a muckle for the country.

I had the pleasure of conducting a test recently in which twenty automobiles of various makes each traveled 1000 miles, traversing five States, including New York and the District of Columbia. Some of them used gaso-

[6] "Fuel for Automotive Apparatus," by E. W. Dean, JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS, vol. 2, No. 1 (January, 1918), page 47.

line and some kerosene with a small quantity of gasoline separately used for the purpose of starting and warming up. The consumption was markedly decreased in the case of all the cars which used special applications of heat in the vaporization of fuel. An increase of mileage per gallon of fuel of 50 per cent was general, including those using kerosene. The engines of most of the kerosene users showed little or no carbon and their crankcase oil condition was generally excellent. They required but little more attention than the gasoline cars. The educative value of such publicly conducted tests is inestimable. I apprehend that coordinated effort on the part of the producer, the refiner and the automotive manufacturer along such lines will discover the pearl to the user. That done, the way to save the wastage from the oil well to the user will be easier. I ask that a committee be appointed to coordinate the powerful interests on the problem, and to formulate the mechanism necessary for attainment of the end in view.

JOSEPH E. POGUE:—Dr. Dean clearly points out the pivotal bearing of cracking upon the engine fuel supply. As matters now stand, the automotive future is dependent upon the competency of cracking to a degree difficult to exaggerate, and the importance and potentiality of this principle should not be underestimated. Cracking, if unaffected by retarding economic factors, can apparently expand over a course of years so as to lead to a doubling of the supply of gasoline as compared with the quantity obtainable without its aid. Also there are reasons to believe, although substantiating figures cannot be adduced at the present moment, that the operating cost of the process in widest use is fairly slight. But in placing reliance upon cracking, the automotive industry should not fail to consider the retarding factors that Dr. Dean mentions, as well as others, including patent limitations, the time required for the acceptance and installation of cracking processes by refineries not already so equipped, the difficulties in respect to favorable yields with asphaltic crudes and possible restrictions in expansion for purposes of financial advantage. There are few subjects that stand more in need of adequate economic study than cracking. The matter can scarcely be properly valued with the data in hand. In the imperfect light that now falls upon this matter, however, it appears that the principle offers a growing increment to the gasoline supply, but one that scarcely can be sustained in sufficient magnitude unless the automotive apparatus, at least, permits the supply of gasoline at the same time to expand in such direction as to include successive strata of the kerosene cut, the area least affected by cracking possibilities.

So much is discernible ahead with some measure of clearness.

CHAMPAGNE

COL. WILLIAM HAYWARD'S story of the battle in Champagne is perhaps the most vivid told to date. "During the Champagne offensive," he said, "we had concededly the worst Boche stronghold from Switzerland to the sea, just a few kilometers west of the Argonne Forest. The 'Hell Fighters' were still with the French division under General Gouraud. We knew in advance that we were to attack, and we were all tuned up for the occasion. I was glad, because we needed the time, and it also gave us a chance to see the wonderful preparations, the assemblage of the shock units of infantry, of pontoon trains, aviators, artillery and ambulances.

"For days ammunition trains and supplies poured in. The various units had time to take stock. Mere skeletons of regiments were given replacement troops. The enemy land opposite us was high and gave the Huns absolute control, for the time being, of the surrounding country. The engineers came up and were ready to follow our advance and clean up the roads and bridges. There were strong German machine gun posts ahead of us.

"The artillery preparation of the French was to be for about 7 hr., starting around midnight. According to General Gouraud, it was the greatest assemblage of artillery in any one spot in the world's history.

"There were hundreds of big cannons. The roads were congested with big guns, motor trucks and wagons. Field and horse artillery were also in readiness, and back of all was the monster American naval guns with their snouts up in the tree tops.

"While we were all waiting for our barrage fire to start, one of the Big Berthas whizzed over us and exploded behind our lines. We all jumped. The night lit up like Luna Park, Coney Island and the Great White Way combined.

"The riot started. Suddenly there was a burst of flame. A storm of machine gun bullets cut the air like rain and hail. Many concrete walls several feet thick with tiny orifices for machine guns inside were blown to bits, blockhouses with glorified pill boxes were blown to atoms.

"The roaring sound of our artillery and the shells bursting on the German lines could not be described. Our barrage seemed to be fired but a few feet over my head and at times I believed I could have put up my hand and touched the shells. One could actually feel them whiz by one's hair.

"Some of my lads went to sleep despite the terrific thundering of the guns. But when the time came to advance everybody was ready. For 12 continuous days we crossed rivers, captured towns, stormed bluffs and slopes, ridges and hills, and captured tremendously strong enemy positions. We had only the sound of our barrage fire to guide us. The Germans did not know that a force was finding its way into their midst until we were actually on top of them. We captured hundreds of prisoners. For 12 days our shell fire was completely lambasting them and we gained about 14 km.

"We met almost irresistible waves of infantry at times, but after hand to hand encounters managed to sweep them back. The Germans were tired out and afraid of the 'black demons' during the last days of the onslaught.

"When we crossed the Darmois River, where it widened into a swamp, the Huns shelled us industriously, and it looked like a rainstorm on the surface of the water. Shells broke from percussion when they hit the water. To be heard we at times had to shout in one another's ears.

"We gained our objective after 4 days and nights and surmounted a great ridge known as Butte, overlooking towns, lakes, farms and a wonderful valley dotted with chateaus.

"From there I witnessed the most wonderful sight of the battle. It was four enemy divisions attacking in perfect liaison. They covered a front of 4 miles. The 'Hell Fighters' were in the center of the Allied division, which was the center of the four attacking divisions. The artillery was close behind us, and the German artillery behind their troops, and what a battle it was! Each army's artillery was firing on the advancing infantry.

"This made a double belt of flame, smoke and tossed up men. The sky was full of aircraft. We were constantly in the atmosphere of gas, but fortunately it was phosgen and arsene, and not the deadly mustard or yperite gases. But, nevertheless, it took the lining out of our nostrils, throats and lungs, and we cried like onion peelers.

"When the offensive at that time was over we came out with but twenty officers. The loss in troops was exceedingly heavy.

"The regiment received the Croix de Guerre after the battle. I think 132 officers and men were individually given Croix de Guerre for exceptional bravery."

—*New York Evening Telegram.*

Variable-Speed Governors

By W. W. Wells[1] (*Member*)

Minneapolis Section Paper *Illustrated with* Charts and Drawings

SOME years ago, I think in 1903, while I was employed by the Ball engine people, they equipped some engines intended for use in a paper mill with a governor that was adapted to allow the engine to run at a variety of speeds. This was done by taking an ordinary Pickering governor and driving it by a speed-changing pulley. As I recall it, the requirements of the paper mill were that the engine should be able to govern through a wide range of speeds. With the speed-changing pulley the ratio of the drive between the engine shaft and the governor could be varied, and, since it was the speed of the governor shaft that determined the position of the throttle, the governor shaft ran always at the same speed, while the engine ran anywhere from perhaps 600 to 200 r.p.m.

I wish to call your attention in the first place to the formula for centrifugal force. This is

$F = 0.0000284\ WRN^2$, in which

W = weight in pounds
R = radius or distance from the axis in inches
N = number of r.p.m.

When we design a governor, W becomes constant and R varies according to the position of the throttle. With the weights in the inner position the throttle is open, and the weights move out a certain amount in closing the throttle; hence R varies within a definite range. The force varies also as the square of the number of revolutions. If we are figuring on one speed only, all the factors except R become constant and our problem is comparatively simple, because we can make a spring the pull of which will increase at the same rate as R increases. If, however, we want to govern accurately at different speeds, our spring must have characteristics for the high speed which differ from those for the low rate. Since the force varies as the square of the number of revolutions, if we double the speed we quadruple the force, and since the centrifugal force is balanced by the spring, we must quadruple the spring pressure. As the increase in centrifugal force, due to the increase in R, is four times as great, we need a spring that is four times as stiff. Doubling the speed requires a spring pressure four times as great and a spring stiffness four times as great.

Most governors are adjustable, that is, you can increase or decrease the pressure on the spring, but the stiffness remains the same and is correct for but one speed. To make this a little more concrete, let us assume that we have two weights of exactly 1 lb. each and that when they are in their inner position they are 1 in. from the axis and in their outer position the center of gravity is 1½ in. from the axis. Assume also that the leverage with which the weights act on the spring is unity; then the pressure on the spring will be exactly equal to the sum of the centrifugal force of the two weights.

Let Pc and Po represent the force exerted by the spring when the throttle is closed and open respectively. Then, since

$$P = F \qquad W = 2$$
$$Rc = 1\tfrac{1}{2} \text{ and } Ro = 1$$

we can substitute these values in the formula for centrifugal force ($F = 0.0000284WRN^2$) and we shall have for this arrangement of weights

$$Pc = 0.0000852\ Nc^2 \quad (1)$$
$$Po = 0.0000568\ No^2 \quad (2)$$

If we wish this governor to control the speed within 2 per cent when the idling speed is 1600 r.p.m., we will make Nc 1600 and No 1568. Substituting in equations (1) and (2) we have $Pc = 218$; $Po = 140$; hence

$$Pc - Po = 78.$$

Since the movement of the spring is ½ in., its stiffness should be 156 lb. per in. For convenience let us use a 160-lb. spring. This will cause a drop in speed of about 2½ per cent; then

$$Pc - Po = 80 \quad (3)$$

Equation (3) holds as long as we use a 160-lb. spring, and these three equations will enable us to calculate the variation in speed as the load varies for any setting. The table shows the results for a number of different settings. When set to run idle at 1599 r.p.m., the speed falls to 1558 when the throttle is wide open. We could tighten the spring enough to make the idling speed 1700 r.p.m.; the speed under load would then be 1709, and we should have an extreme case of hunting, since we would be trying to make the engine run faster when fully loaded than when idle. If we back off the spring adjustment to make the idling speed 1400 r.p.m., it drops to 1237 under load. If set to idle at 800 r.p.m., the throttle never gets wide open.

Throttle Opening and Engine Power

This is not the whole story, however. The case is not quite as bad as it looks, due to the fact that it is not necessary to have the throttle wide open at low speeds to get almost the full power of the engine. In making a test of a governor in which a butterfly throttle was used, we measured the position of the arm operating the throttle at each reading and found that when the weights had moved a quarter way out the engine was developing about 20 hp. whether the speed was 800 or 1600 r.p.m., and with the weights half-way out the power was 30 hp. or more at speeds above 1000 r.p.m. When the weights were three-quarters out and the throttle three-fourths open we had very nearly the full power of the engine. I have made calculations for five different throttle positions by taking three points equally spaced between open and closed positions, *i.e.*, making $Ro = 1$ in.; $R_1 = 1\frac{1}{8}$ in.; $R_2 = 1\frac{1}{4}$ in.; $R_3 = 1\frac{3}{8}$ in.; $Rc = 1\frac{1}{2}$ in., and $Po + 20 = P_1$; $P_1 + 20 = P_2$, etc., and find that when set for an idling speed of 1599 r.p.m. we have 1592 r.p.m. with throttle one-quarter open, 1583 at half throttle and

[1]Engineer, Clyde Cars Co., Clyde, Ohio.

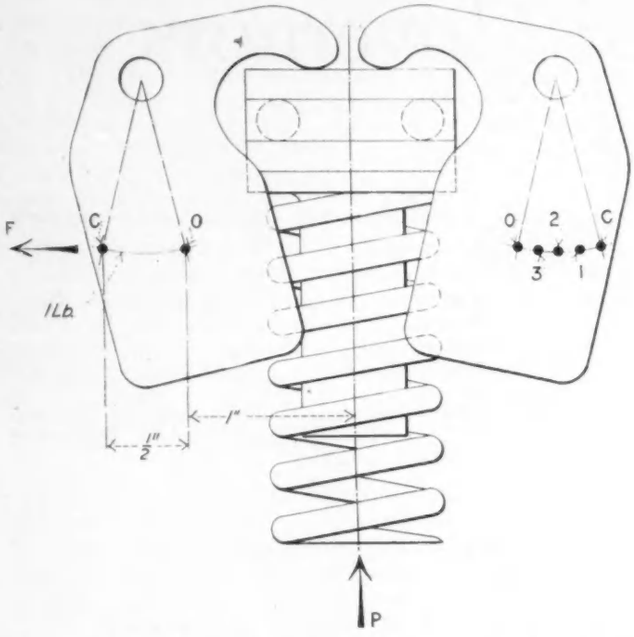
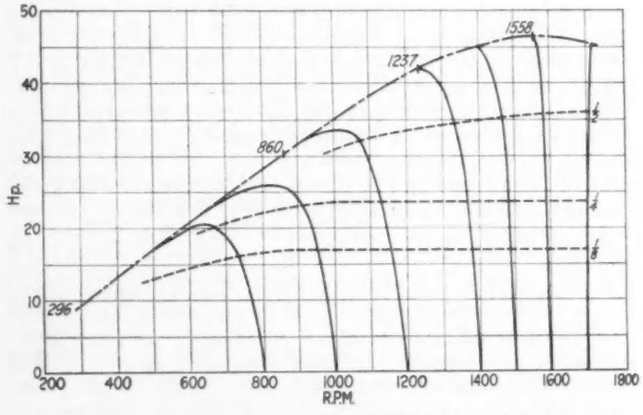


Diagram Showing Typical Relation of Governor Weights and Spring

1558 with open throttle. These values if plotted show a drop of 7 r.p.m. at 20 hp., 16 at 35 hp. and 41 at full load; a total range of 2½ per cent. At 1500 r.p.m. the total drop is 97 r.p.m or 6½ per cent, at 1400 r.p.m. 11½ per cent, and when idling at 1000 r.p.m. the speed falls off to 296 r.p.m. under load. The curve, however, instead of being a nearly horizontal straight line, takes the form shown, because the power runs up to 20 hp. during the first quarter of the throttle movement.

What I want to call your attention to here is the fact that it is impossible to govern anywhere near as closely at reduced speeds as at the speed for which the governor is designed, although this defect is minimized somewhat by the fact that we do not need full throttle opening at low speeds.

Now the above is theory, but it represents a limit that we cannot hope to exceed with the usual method of mounting the spring. Another set of curves shown represent practice, the results of a test of a well-known engine with its governor adjusted for maximum and minimum speeds. The shape of these curves is not ideal and no doubt can be improved considerably; what I am



Curve of Results of Several Different Governor Settings

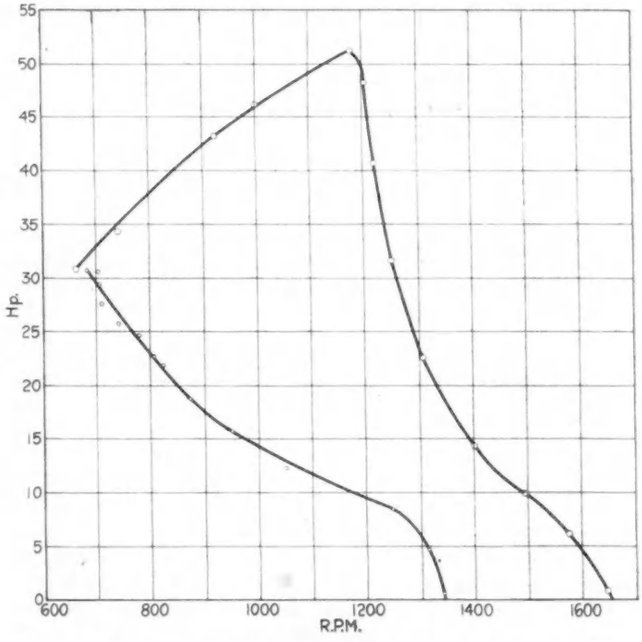
concerned with is the fact that when set for maximum speed, the upper part of the curve is nearly vertical, while at the low-speed setting the inclination is very marked.

Throttle,	Open	¾	½	¼	Closed	Increase per cent
Speed, r.p.m.,	1,709.5	1,706.1	1,703.3	1,701.1	1,699.2	—0.6
	1,558.6	1,572.4	1,583.3	1,592.2	1,599.6	2.5
	1,404.2	1,437.2	1,461.5	1,484.0	1,501.2	6.4
	1,237.0	1,294.0	1,336.0	1,372.0	1,400.0	11.6
	860.0	985.0	1,074.0	1,129.0	1,196.0	24.0
	296.0	625.0	796.0	912.0	999.0	70.0
	.....	28.0	459.0	669.0	803.0	....

The governing is satisfactory at high speed and heavy loads but poor at low speed for all loads.

Let us go back to equation (3) representing the variation in spring pressure due to movement of the weights. This holds no matter how the governor may be set, because the spring has the same stiffness under all loads. It takes 20 lb. to compress it the first ⅛ in. and an additional 20 lb. for every added ⅛ in., and its movement is always ½ in. as the throttle moves from open to closed positions. For isochronous governing $Nc = No$, therefore, from (1) and (2), $Pc/Po = 1\frac{1}{2}$, or, in general terms, the ratio of Pc and Po must be a constant, but from (3) we see that the difference is a constant. Both of these conditions can be satisfied at only one speed. To get a governor that will govern accurately through a wide range of speeds we might (*a*) use a spring that is stiffer under heavy loads or (*b*) mount the spring in such a way that it will be moved farther at high speeds than at low ones. Either method will get away from equation (3).

I have made some sketches of a governor of the first type, but have not as yet built any that way. We have



Results of an Engine Test in Which the Governor Was Adjusted for Maximum and Minimum Speeds

worked out two slightly different designs in which the travel of the spring varies according to the speed at which the engine is running. One of these has been in use on the Clydesdale trucks for a number of years. Our weights are inside the housing and are very similar to those you find in almost any flyball governor. The shaft carrying the arm seen at the right is connected at the

other end to the throttle in the carbureter. Clockwise motion opens the throttle. The centrifugal force of the weights tends to rock the shaft in a counter-clockwise direction. The spring is attached to the lower end of this arm and its other end is carried by the upper end of the lever at the left. This lever rocks on a fixed support at its lower end. Moving this lever to the left stretches the spring and at the same time moves it away from the shaft, so that the leverage with which it acts on the shaft is increased. This increase in leverage has the same effect on the rocker-shaft as increasing the stiffness of the spring would have if there were no change in leverage. I have spoken of the extension of

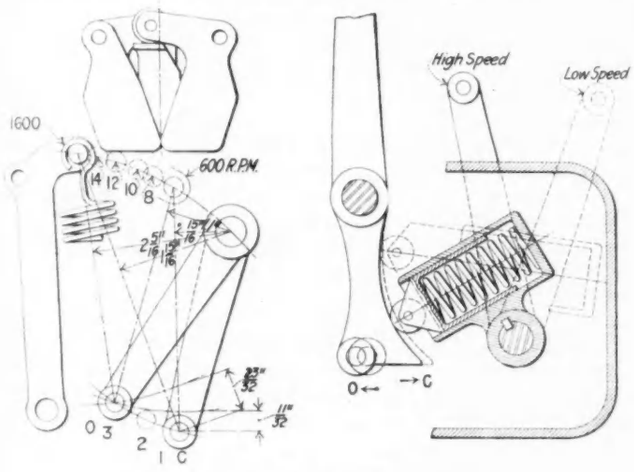


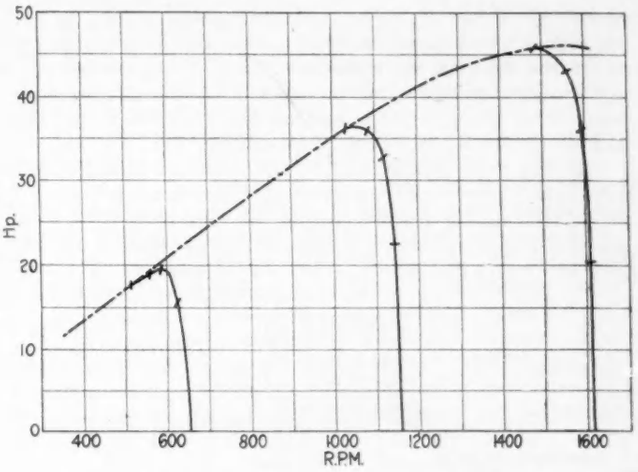
Diagram of a Typical Truck Governor

the spring as being greater at high speeds than at low. In this case, with the spring lever set for high speed, the spring is stretched 23/32 in. as the throttle closes, while at the low-speed setting it is only 11/32 in. If we allow the spring lever to swing to the right until the center line of the spring intersects the axis of the shaft we will have a spring movement of 0 in., leverage 0 in., spring pull 0 in., and speed 0 r.p.m.

Test Results of Two Types of Governor

The test proved that this governor is not quite as well proportioned as it might be, and I have since made some calculations on another governor of this type in which I expect to get better results. This too is theory; it has not yet been reduced to practice. This shows for the idling position, one-quarter throttle opening, one-half, three-quarters and full-open throttle, 1616, 1605, 1590, 1555 and 1480 r.p.m. This means 8½ per cent total variation. At another setting the speeds are 1159, 1141, 1118, 1086 and 1028 r.p.m., or 11½ per cent variation. At 600 r.p.m. we get 21 per cent variation, but we use only half of that, since we do not require the full opening of the throttle at that speed. It may be possible to straighten out these curves by rearranging the parts connecting the weights to the throttle so as to make the movement of the weights more nearly proportional to the power the engine develops.

But to return to practice. A test of our present design of governor gives results as shown. The shape of these curves is not ideal, but it is about as good as any governor curves that I have seen. Notice, however, that the shape of the curves for 1600, 1400, 1200, 1000 and 800 r.p.m. is almost identical. There is one feature of the design that may prevent us from getting ideal re-



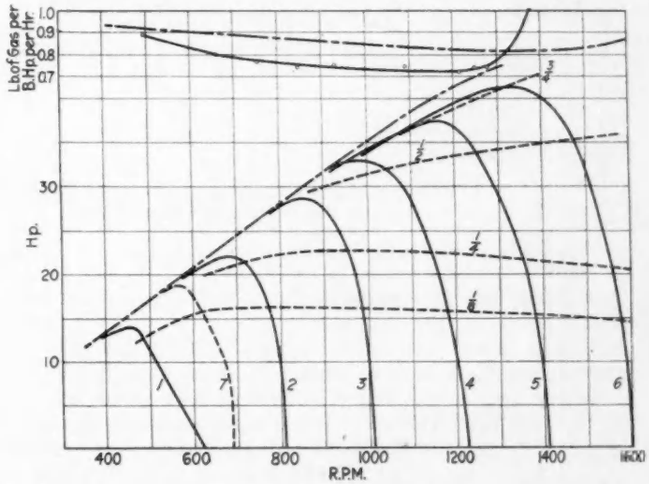
Theoretical Results with a New Type of Governor

sults at all speeds, and that is the fact that the distance from the axis of the rocker-shaft to the center line of

Throttle,	Open	¾	½	¼	Closed	Increase per cent
Speed, r.p.m.,	1,868	1,954	1,988	2,000	2,001	6.5
	1,480	1,555	1,590	1,605	1,616	8.5
	1,028	1,086	1,118	1,141	1,159	11.5
	512	554	588	623	654	21.0

the spring varies somewhat as the arm changes its position.

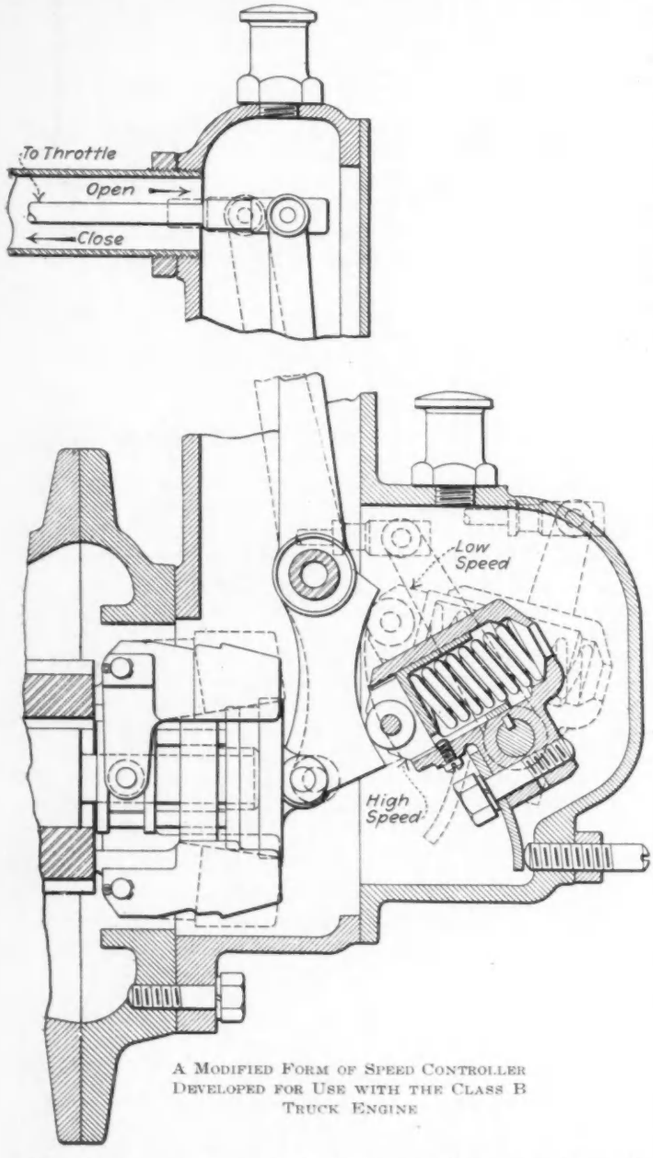
There is one result shown by this test for which I have no satisfactory explanation. The broken line shows the horsepower curve with the governor disconnected and the throttle held wide open. Each test with the governor was made by increasing the load until the throttle was wide open, and in most cases until the speed was reduced to 500 r.p.m. or less. The gasoline consumption was determined at each reading and the results are plotted on the diagram. The broken line shows results with the governor disconnected, the lowest value being 0.82 lb. per hp.-hr. The full lines show results with the governor controlling the throttle, the lowest value being 0.70 lb. per hp.-hr., and it is only after the throttle is about half closed that the consumption exceeds that shown with the governor disconnected. We do not claim a 12 per cent increase in fuel economy, although these figures seem to



Actual Test Results of a New Governor Where the Load Was Increased until the Throttle Was Wide Open

prove it. I had thought that this result might be explained on the ground that the carbureter is less efficient when the throttle is wide open than when nearly but not quite wide open, but a number of these runs were made with the governor holding the throttle wide open and yet reducing the fuel consumption.

We call this governor a "controller" to convey the idea that it does more than the ordinary governor used on motor trucks, and because it has complete control of the throttle at all times. It is connected directly to the throttle in the carbureter. We use no auxiliary throttle.



A Modified Form of Speed Controller Developed for Use with the Class B Truck Engine

The driver has no control of the throttle except through the controller. He sets his lever for the desired speed and then leaves the controller to manage the throttle. The spring lever is connected by a rock-back to the accelerator and to the throttle-lever on the steering-gear, so that the operation of a truck equipped with this governor is practically the same as on any truck where you have a combination of a hand-controlled throttle and a foot accelerator. If you are driving at a uniform rate on level road you might not realize that you had anything unusual, but when you strike a grade the truck keeps going at the same speed without any adjustment of the levers, and when you reach a down grade or throw out the clutch the engine does not speed up. The driver uses the lever to change the speed instead of to change the power. This is exactly the design that has been used on the Clydesdale trucks since 1914.

This governor is mounted on the Continental model C or model E engines without any change in the design of the engine or any additions. We are now building the slightly modified form illustrated for use on the Continental model B engine, which is the engine used on the Class B Government truck. We remove the spring ordinarily furnished with the governor, put in new weights and a compression spring working in a guide and operating through a roller on a cam surface on the lever. The full lines show the spring in the high-speed position. Here the spring is compressed considerably and is acting on the lever at some little distance from the fulcrum; hence it has considerable leverage. The spring and its housing are carried on a shaft that extends through the housing to a lever on the outside, which connects with the accelerator and hand lever on the steering-gear. Releasing the pull on this lever allows these parts to swing back to the position shown by broken lines; here the spring is compressed but little and is acting at a short distance from the fulcrum of the lever. This is the low-speed position. We are just beginning to sell trucks with this type and have not yet made a dynamometer test. So far as we can judge by the behavior of the truck, it is equal to the other type, and I believe can be made to give slightly better results.

Each of these types is provided with a stop screw that determines the maximum speed. When testing the truck we set this stop for the speed limit desired and fasten it with a seal. Some of you are probably thinking that the exposed working parts seen in the first type give a reckless driver a chance to hitch something on that will enable him to drive faster than the maximum for which the governor is set. The fact that the driver has no control of the engine except through the controller reduces this temptation considerably. If he puts it out of use he must rig up some other means for controlling the throttle. However, the drivers seem to like the controller very well. The design just described is completely housed, and the other could be so protected but not quite as easily.

The Discussion

Chairman H. C. Buffington:—Mr. Wells has described something that is extremely interesting. There are many places where governing at a certain speed is desirable; for instance in threshing, where pulleys are of different diameters and whatever is being operated is running faster. Here, it seems, the engine can be slowed down and still maintain a governing speed.

Mr. Wells:—I would like to ask one question. I notice in one of the tractor indexes under specifications of tractors built in Minneapolis, that the belt speeds vary from 2000 to something like 4700 ft. per min. The S. A. E. Standard, I understand, is 2600 ft. per min. Is the one speed satisfactory, and, if so, why is it not more commonly used?

Chairman Buffington:—I think that every firm manufacturing tractors is trying to get to that one speed. It must be remembered that this standard has been in existence for a short time only. It will take longer to consider and adopt it. I would like to ask just where a variable-speed governor will be worth the extra cost? The simpler a governor is, the fewer the moving parts,

the more desirable it is, and one that will govern within 10 per cent will usually be satisfactory. On trucks a sensitive governor is not wanted for the reason that when stalled it is desirable to have the engine speed up a little.

MR. WELLS:—In one design of engine I have recently figured on, the additional cost would be for the spring lever and the boss to mount it on. The governor already has the rocker-shaft, the lever on the rocker-shaft which is connected with the throttle and the spring attached to the lever. It has a control quite similar to that used on a well-known tractor, which is entirely through the governor, with only one throttle, the one in the carbureter, but instead of the lever arrangement that we use it has a spring that pulls straight back. This means that the control is similar to ours but that the accuracy of the governing at low speed is decreased.

A. F. MOYER:—In designing the ordinary governor you run into hunting at high speeds and poor regulation at low rates. I believe that in arranging the spring to change the leverage for different conditions, Mr. Wells has something valuable.

MR. WELLS:—How much of a demand is there for variable speeds in tractor work? If there is as much variation in land conditions elsewhere as we have in Michigan, some variation in speed would seem to be desirable, as well as some changes in speed for belt work. One belt speed can hardly be entirely satisfactory for all belt-driven machines any more than one speed is adapted to all kinds and conditions of soil and all kinds of farm work.

W. J. MCVICKER:—A chance to regulate speeds might be desirable in some cases, especially in corn plowing. There it is needed in going across a field at 2 to 3 miles per hr. That is about the only place I can think of where it would be needed.

CHAIRMAN BUFFINGTON:—In plowing work I would be afraid of the variable-speed governor, because when you throttle an engine down you are overloading it. Naturally, a farmer will put on all the plows he can at the recommended governing speed of the machine. He will not use two plows at 2 miles an hr. when he can plow 3 miles per hr. I can see that variable speed is desirable in belt work where a fine-haired adjustment is demanded, but I question the cost. If there is to be little or no difference in cost and no more working parts are required. I should not hesitate to endorse it.

H. W. ADAMS:—I did considerable operating a few years ago while with a company that had a tractor with a variable-speed governor. The speed could be changed, as Mr. Wells has described, from the driver's seat, and it was one of the finest things I ever saw in a tractor. In plowing many different conditions of soil are met; sometimes you are in rocks and sometimes in stumps. If you have a one-man machine and come to a rough, rocky spot, you want a governor that can be set for from ½ to 2 miles per hr. The Twin City engine made a few years ago had a governor that could be changed from the seat. I believe that when Mr. McVicker was out in the country he satisfied himself that it was a good thing. I, personally, think it is very desirable that the operator have some means of changing the speed. If you can set a tractor to run, say, 1 mile per hr., you can go back, attend to the plows and pull out the rocks. You do not want the machine to stop; you want it to creep. Mr. Wells has something that is worth considerable to tractor manufacturers. I know it will meet with favor among the farmers, especially in uneven country. I believe it is a good thing.

MR. WELLS:—What Mr. Adams has said is right along the line of my experience. I had one field made up of boulders and there I had the horses travel very slow to save my ribs. In another field with light soil and not a boulder, I could put on a sulky plow and three horses and make them walk right along. There must have been a difference of 50 per cent in the speed under those conditions. I find myself questioning another condition. I have never operated a tractor plow. When the plow comes out of the ground, do you have to manipulate the throttle or do you set it in the position for maximum speed so that the governor will act? Would it not be more convenient at the turns to reduce the speed but still have it on to take up the load?

MR. ADAMS:—In a large machine with a number of plows and even where there is an extra man, the tractor is generally throttled down to run slowly and give the operator a chance to drop the plows. In that case it would be a good idea to have the governor maintain constant speed while the operator goes back to put in the plows and then jumps on. I believe it would be a good thing both in putting the plows into and taking them out of the ground, especially on a one-man machine.

MR. MCVICKER:—The greatest objection is that most engines are efficient at one speed only, and when you change this they operate at lower efficiency.

CHAIRMAN BUFFINGTON:—I am very glad Mr. McVicker brought that point out. In designing a tractor engine it is desirable to have the revolutions just above the point of maximum torque, so that when the engine has a maximum load it still maintains maximum torque. Below maximum torque the engine is overloaded and will pound. An engine operated at a speed of 400 r.p.m. is below its maximum torque and is overloaded.

BENZOL FOR ENGINE FUEL

THE Committee of the National Benzol Association has issued the following specification for benzol for use as engine fuel:

(1) Specific gravity, 0.870 to 0.885
(2) Distillation test (by flask):
Benzol shall give a distillate of not less than 75 to 80 per cent at 100 deg. C
Benzol shall give a distillate of not less than 90 per cent at 120 deg. C
Benzol shall give a distillate of not less than 100 per cent at 125 deg. C
(3) Sulphur shall not exceed 0.40 per cent
(4) Benzol shall be entirely free from water
(5) Color shall be water white
(6) Rectification test: 90 c.c. of the sample shaken with 10 c.c. of 90 per cent sulphuric acid for 5 min. should not give more than a light brown color to the acid layer
(7) Benzol shall be entirely free from acids, alkalis and sulphuretted hydrogen
(8) Benzol shall not freeze at 25 deg. fahr. below the freezing point of water

Such a specification should insure general freedom from trouble with this fuel. The tendency which pure benzol has to freeze readily is amply provided against, and this is a good point. The negligible amount of sulphur allowed is also satisfactory, as with it no cylinder corrosion is likely to occur.

—*Motor* (London).

Lubricating Oil Research Program

A SUGGESTED guide to the prosecution of a research on lubricating oils, particularly those intended for use in internal-combustion engines, has been prepared by the Bureau of Standards.

Lubricating Oil Program

GENERAL PURPOSE

The general purpose in issuing this outline is to collect as much information as possible pertaining to the many problems involved in the lubrication of internal-combustion engines. The majority of these problems have been well recognized in the past, but their real importance and the necessity for their solution have been further emphasized during the war, especially in aircraft and farm tractor engine operation. The secondary purpose is to determine the real value and importance of laboratory methods now used in oil testing and of the significance of the results as an indication of the value of oils in practical service. It is hoped that new tests of value may be developed to supplement those now in use.

It is the earnest desire of the Bureau to secure the wholehearted cooperation of oil refiners, large and small, oil users and other interested parties in this investigation. All suggestions for the improvement of the program and constructive criticisms of it from any source will be heartily appreciated.

So far as present knowledge goes, the ideal lubricating oil should possess the following characteristics:

(1) Maximum reduction of friction
(2) Minimum amount of wear of rubbing surfaces
(3) Maximum length of time that oil can be used in service
(4) Minimum rate and minimum amount of decrease in lubricating efficiency
(5) Minimum carbonization in combustion chambers
(6) The greatest security against seizure consistent with maximum lubricating efficiency.

It is proposed to determine what oil or oils most nearly approach this ideal.

SOME SPECIFIC PROBLEMS

(1) To determine the cause of reduction of lubricating efficiency, i. e., whether it is due to change in viscosity alone or to the presence of decomposition products in the used oil or to both of these factors.

(2) Does the lubricating efficiency of an oil depend upon any characteristics other than those usually recorded in specifications, such as adhesion, specific heat, thermal-conductivity, "body," etc.?

(3) What relationship exists between the flash and fire points of an oil and its boiling point range?

(4) What predictions may be made of the specific consumption of oil in an engine from the values of the flash, fire, and boiling point range? Should the entire boiling point range or any part of the boiling point range of an oil be limited?

(5) What are the relative values of the Conradson carbon residue test and the Waters or other oxidation oven tests as means of predicting the decomposition which will occur in any lubricating oil in service?

(6) Does the presence of emulsifying products in an oil affect its lubricating efficiency in service? What disadvantages in reclamation processes are caused by the use of emulsifiable oils?

(7) Does the presence of colloidal matter such as deflocculated graphite, carbon or carbonaceous matter, affect the lubricating efficiencies of oils? What is the relative value of settled unfiltered cylinder stock which contains colloidal matter as well as solid or semi-solid matter in suspension compared with the same cylinder stock in the filtered condition, when these oils are used for blending with light hydrocarbon oils?

(8) What are suitable oils for use in Gnome or other similar types of rotary engine—castor, mineral blended with castor (using oleic acid as a binder), or mineral blended with other fatty oils?

(9) Is it desirable to blend fatty oils, high or low acidity, with mineral oils, and what effect does the presence of fatty oils have upon the decomposition of mineral oils of paraffin and naphthene bases?

(10) To what extent do lubricating oils of paraffin and naphthene base, blended with fatty oils, absorb fuel vapors?

(11) How can it be judged when an oil has reached such a condition that it should be discarded or reclaimed?

(12) How can the appropriate viscosity or other characteristics of an oil for any given engine be determined, giving due consideration to seasonal changes in temperature, wear of engine parts, peculiarities of lubricating systems, etc.?

(13) What are the relative merits in service of lubricating oils manufactured from paraffin and naphthene petroleums?

(14) To what extent does the character of bearing metals in contact and the condition of their surfaces influence lubrication?

Engines and Engine Test Methods

It is proposed to make tests of oils in the following aviation engines:

(1) Liberty twelve-cylinder
(2) Liberty six-cylinder
(3) Hispano-Suiza 150-hp.
(4) Gnome rotary

MECHANICAL CONDITIONS

Record peculiarities of engine lubricating systems, bearing clearances, specific bearing pressures, compression ratio, type of pistons and rings, piston clearance and all other mechanical features of importance. The large bores in the crankshaft should be plugged with aluminum to facilitate removal of oil from the system without taking down between tests if desired.

RATE OF OIL FLOW

The oil flow from the pump to bearings will be measured by a venturi. If possible the actual rate of oil flow through all bearings should be determined at the normal speed of the engine by direct measurement.

RUNNING RECORDS

Barometer, Temperature, Inlet Air, Humidity

Constant	*Variable*
(1) R.p.m. of engine	(1) Horsepower
(2) Fuel consumption	(2) Oil consumption
(3) Jacket water inlet temperature	(a) Burned
(4) Temperature of inlet to oil-pump	(b) Leakage
(5) Oil pressure	(c) From breathers, (vapor)
	(3) Temperature of outlet to oil cooler
	(4) Temperature of oil from crank-pin cheeks
	(5) Water outlet temperature
	(6) Condensate from breathers
	(a) Oil
	(b) Volatile
	(c) Gas

TEST PERIODS

It will be necessary to determine whether the same amount of decomposition can be obtained in 1-hr. runs, as in 5-hr.

or longer periods. A standard test period will be chosen for all tests.

SPECIAL TESTS

Fuel Absorption Runs should be made with paraffin and naphthene base lubricating oils using dry gasoline vapor, aviation gasoline and average automobile gasoline as fuels with each oil to determine the relative amount of fuel absorbed by each and the character of the compounds absorbed.

Carbon Deposits Runs should be made with paraffin intermediate and naphthene base lubricating oils and a record made by photographing the piston-heads and noting the amount and character of the carbon deposits on the remainder of the explosion chambers.

STANDARDIZED TEST FUEL AND LUBRICATING OIL

A sufficient quantity of aviation gasoline made from the same refinery distillate should be provided for the completion of all engine tests. Whenever any change is made in fuel, a standardized lubricating oil should be used to determine whatever variation may occur because of the change.

It is highly advisable to standardize some lubricating oil for use during all engine tests to check any variation other than that caused by lubricating oil. A sufficient quantity of this oil should be provided to meet the requirements of all check tests.

THEORY OF LUBRICATION

ADHESION

Determination of method or methods of measuring adhesion on the following groups of oils:

(1) Hydrocarbon oils of different bases, and each of different viscosities and volatilities
(2) Fatty oils—prime lard, "acidless" tallow, castor and sperm, also these with different proportions of oleic acid, cotton-seed, etc., also cutting oils
(3) Blends of hydrocarbon oils and fatty oils, also hydrocarbon and castor blends with oleic acid as a binder

Study of cutting oils, and the bearing cutting oil properties have on lubrication. Power consumption for cutting operations with and without cutting oils.

STUDY OF OIL FILMS

(1) Behavior of films at constant temperature on plates also on a plate with temperature gradient, to determine drainage and rate of spread.

(2) Behavior of films on different metals with localized heating.

(3) Behavior of films on water, as a possible means of throwing additional light on the present knowledge of oil films as applied to lubrication.

THERMAL PROPERTIES

Specific heat, heat conductivity and thermal expansion on the groups of oils given under Adhesion.

FRICTION MACHINES

The practical usefulness of friction machines in general has been widely commented upon and questioned in the past. To settle definitely the real value of friction machines the following program of investigation is proposed;

(1) Study of present stage of the art
(2) The analysis of all existing machines comprising the following general items:
  (a) Information is desired as to whether a reading can be made of the critical point of film break-down, *i. e.*, incipient seizure of bearing at different loads, speeds and viscosities at the temperature of oil film in the bearing; also when using different bearing metals
  (b) Method of applying lubricant to rubbing surfaces
  (c) Method of regulating all operating conditions
  (d) Recording devices, automatic or otherwise

In the preparation of the above analysis it is desirable to draft a chart in which as much information as possible can be given in tabular form for direct comparison.

With all the above data at hand, complete detail specifications should be prepared of an ideal friction machine on which the desirable determinations could be made.

Division VIII, Metallurgy, and the division studying lubricants will cooperate fully with reference to bearing metals and tests.

ROUTINE TESTS

FRESH AND USED SAMPLES

(1) *Gravity*
(2) *Flash*
(3) *Fire*
(4) *Viscosity* (Saybolt Universal) at 100, 150, 212 deg. fahr.
(5) *Color* (a) Fresh
  (b) After heat test
  (c) Used oil from engine
(6) *Emulsion* Coles shaker
  Demulsibility Herschel stirrer

Note: Oils more viscous than 50 sec. at 212 deg. will be blended in equal proportions with standardized petroleum ether for shaker emulsion tests.

(7) *Cold Test* American Society for Testing Materials method.

SPECIAL LABORATORY EXAMINATIONS

CARBON RESIDUE

Carbon residue values will be determined by the Conradson carbon residue apparatus as described in the *Proceedings* of the American Society for Testing Materials. All outside oil samples and special engine test oil samples will be subjected to the Conradson test.

OXIDATION OVEN

All oil samples, both outside and those used in special engine tests, will be subjected to tests in both the Waters and Stratford oxidation ovens for the following determinations: (1) evaporation loss, (2) petroleum ether insolubles, (3) "varnish"—resins.

In making a general study of the susceptibility to oxidation of engine oils full consideration should be given to constitution and methods of manufacture of anhydrous switch and transformer oils. The same remark applies to viscous "water-white" oils, such as Squibbs or Nujol medicinal oils.

STANDARDIZED PETROLEUM ETHER

In making petroleum ether insoluble determinations it is imperative that the same standardized petroleum ether be used throughout all tests. Specifications for standardized petroleum ether are as follows:

Gravity, Baumé 77 to 80 (incidental)
Initial Boiling Point 110 to 120 deg. fahr.
Final Boiling Point 220 to 245 deg. fahr. Unsaturated content not over 4 per cent (Bureau of Mines Method).

Note: Above distillation range determined by Saybolt distillation method.

VOLATILITY

It is desirable to investigate by distillation the volatility of the different compounds contained in lubricating oils. To make this investigation properly it may be necessary to determine a part of the boiling point range or the whole of that range.

There are four general distillation methods applicable:

(1) Destructive distillation under atmospheric pressure
(2) Dry distillation under high vacuum, 40 to 50 mm. of mercury
(3) Distillation under high vacuum, 40 to 50 mm. mercury, with the introduction of superheated steam.
(4) Distillation under atmospheric pressure with the introduction of superheated steam

It is proposed to determine by experimentation which of the above four methods is most applicable to the study of

the constituency of lubricating oils with least decomposition of oil and with the most concordant results.

OTHER DETERMINATIONS

(1) Sulphur content, (2) ash, (3) fatty oils, (4) acidity, (5) alkalinity, (6) tarry or suspended matter, (7) moisture, and (8) odor.

List of Oil Samples for Examination

COMMERCIAL OILS

A 2-gal. sample of all available American hydrocarbon oils, intended for the lubrication of internal-combustion engines, will be examined for their physical and chemical characteristics. This list of oils will comprise all of those now sold in sealed containers and having reasonable distribution and volume of sales. These oils will not at present be run in the engine tests. It is proposed to purchase these samples at regular intervals, say quarterly, and to retain a 4-oz. sample for reference from each of the samples purchased.

SPECIAL OILS

The following Liberty aero engine oil types will be procured and subjected to a complete examination, including engine tests. Specifications for these oils will correspond to the limits prescribed by Signal Corps Specification No. 3501.

Paraffin Base (1) Lubricating oil made from paraffin base Pennsylvania crude petroleum of high boiling point range (2) Lubricating oil made from paraffin base Pennsylvania petroleum with low boiling point range.

Naphthene Base (1) Lubricating oil made from naphthene base Gulf Coast crude petroleum of high boiling point range (2) Lubricating oil made from naphthene base Gulf Coast petroleum with low boiling point range.

FATTY OIL BLENDS

Fatty oil, prime lard, blends will be made with each of the two oils given above under the heading of Paraffin and Naphthene Bases. The physical properties of these blends will be made to correspond to Signal Corps Specification No. 3501.

The above oils have been selected to determine the difference, if any, in their lubricating efficiencies in service; such differences may occur because of different chemical structure or peculiarities of refining processes applied in their manufacture.

If the data from the tests on this list of oils show marked tendencies, it may then also be advisable to investigate carefully lubricating oils made from natural mixtures of paraffin and naphthene base Mid-Continent crudes or those made from blends of the lubricating distillates from these two crudes at some stage in their manufacture.

MISCELLANEOUS OILS

Various special oils such as (1) prime lard, (2) sperm, (3) castor oil—cold pressed, (4) rape seed oil, (5) rape seed oil, blown, (6) cylinder stock—low cold-test highly filtered, (7) cylinder stock—strained low cold-test unfiltered, (8) "paraffin" and (9) acid treated oils, will be used in the study of the effect of processing methods, i. e., acid treatment, sulpho-compound, etc.; also the effect of filtration to different colors.

Regeneration of Used Oils

It is proposed to make a study of commercial processes applied to the regeneration of used oils and to determine what is the best and cheapest means of converting used oils into good lubricants; also to determine the relative lubricating efficiency of regenerated oils as compared with that of the same oil in its fresh, unused condition.

PROBLEMS INVOLVED

(1) Removal of solids in suspension
(2) Separation (distillation) of very volatile products
(3) Separation (distillation) of light oils
(4) Removal of heavy oxidized compounds by treating with soda ash and blowing with steam
(5) Removal of moisture
(6) Filtration—fullers earth
(7) Blending filtered oil to required viscosity if necessary

PROPOSED SAMPLES FOR REGENERATION

(1) Used oils made from paraffin Pennsylvania crudes
(2) Used oils made from intermediate Mid-Continent crudes
(3) Used oils made from naphthene Texas crudes
(4) Used oils made from California crudes
(5) Used oils made from blends of hydrocarbon and fatty oils
(6) Slop oils consisting of a mixture of oils and greases

UNITED STATES EMPLOYMENT SERVICE NOT SUPERSEDED

THE Emergency Committee on Employment of Soldiers, Sailors, and War Workers, organized by the Council of National Defense, has not supplanted the United States Employment Service, but is assisting and cooperating with it. Col. Woods, assistant to the Secretary of War, and chairman of the committee, has issued a statement in which he points out that the committee is merely a temporary body and that it and the Government departments and boards represented therein will not attempt to create a substitute employment service or in any way take over the functions of the Employment Service. It is the intention of the committee to support the work of the service and to encourage towns and cities through public and private contributions, to carry on local employment offices and bureaus for returning soldiers and sailors which cannot be maintained by the service itself until Congress appropriates the necessary funds.

While the service was compelled to reduce the number of its offices from 750 to 56, due to the failure of Congress to pass the appropriation bill, it has been possible through the assistance of Chambers of Commerce and other organizations to maintain approximately 400 regular offices and over 2000 cooperating bureaus for returning soldiers and sailors. Approximately 35 per cent of the soldiers discharged leave the service without any prospect of a position. The United States Employment Service is placing about 80 per cent of these so that only 7 per cent of the entire number of soldiers discharged either have no positions or remain unplaced after being discharged.

Approximately 5,000,000 applicants were placed by the service in 1918 and the record up to the middle of March indicates that these figures will be surpassed in 1919. In January 372,106 applicants were placed, in February 307,572, and in the first two weeks of March, with some states missing, approximately 212,000 applicants were taken care of.

Vol. IV May, 1919 No. 5

The Liberty Aircraft Engine

By J. G. VINCENT[1] (*Member*)

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS AND CHARTS

UP to the time the armistice was signed, the Government maintained a strict censorship over details of its war equipment, and for this reason very little was known about the details of the Liberty aircraft engine outside of military circles. Since the signing of the armistice this censorship has been lifted, and very complete detail information covering this engine has been published. The cuts and data already published are quite accurate, and hence it seems unnecessary to give a detailed description in this paper.

It was decided to divide this paper into two parts, covering, first, the historical side of the Liberty aircraft engine; and second, a discussion of its features, explaining how these features worked out in actual practice, and what changes in the construction would appear to be desirable after extensive experience with thousands of these engines on the test stand, at the test flying fields, the schools and on the battle front.

The historical side of this development is, in my opinion, one of the very best arguments for reasonable preparedness, and I think that, as an engineer, I would not be doing my full duty to this Society or to our country unless I gave my brother engineers as complete a picture as may be possible of the difficulties encountered due to lack of preparedness in our Air Service when war was declared on April 6, 1917.

I urge all members of the Society to give this matter careful thought and do everything in their power to further the development of military aeronautics in this country, as we may not be so fortunate the next time in having allies to stand between us and the enemy while we spend a year laying the fundamental basis for an Air Service, as was the case in the recent emergency.

I will endeavor to set forth clearly just what happened in extensive use of the engine. It may well be that all engineers will not agree with me in some of my conclusions, but I shall endeavor to be entirely unprejudiced, and my statements will be based on what I believe to be the consensus of opinion of the many experts with whom I was associated in the Engineering Division of the Bureau of Aircraft Production at the time the armistice was signed.

To understand why certain moves were made it is necessary to have a clear picture of the aircraft situation as it existed in this country when we entered the war. We were totally unprepared. The Government had no adequate engineering organization, no production organization, and no samples or drawings of engines, airplanes, instruments or armament of any value for military operations on the battle front; neither did it have any definite information regarding designs being used by our allies. We had to start from absolutely nothing. Realizing the seriousness of the situation, General Squier immediately arranged a number of very important moves, and knowing that the obtaining of proper equipment was very largely a commercial matter, he gathered around him a small group of men of undoubted engineering and business ability. Among these were Howard E. Coffin, Edward A. Deeds and S. D. Waldon. These men, together with General Squier and a few others, began immediately to operate as an Aircraft Production Board.

[1]Vice-president of engineering, Packard Motor Car Co.

EARLY WORK OF AIRCRAFT PRODUCTION BOARD

One of the first moves of this Board was to arrange to send a commission abroad to study airplane designs, make recommendations covering machines to be copied and put into production, and send information about such machines to America at the earliest possible moment. Major R. C. Bolling headed this commission, and took with him Captain Clark, an airplane engineering expert, and Howard C. Marmon, an engine expert. Captain Clark had been head of the very small airplane engineering organization which existed as a part of the Signal Corps at the beginning of the war, and he was chosen because he was as well informed on this subject as any other man in America. Howard C. Marmon was selected as he had had a long experience on automobile engines and was a highly trained all-round engineer. He resigned his position with the Nordyke & Marmon Co. to take up this work, at the personal request of General Squier, and he was commissioned as a Captain in the Reserve Corps after he had been in Europe for some time. This commission left for Europe about June 15, 1917. While these preliminary moves were being made in this country, our allies, realizing our state of unpreparedness, had sent a technical commission to this country to act in an advisory capacity so that we might get something started along the right line with the least possible delay.

A combined group of French and English experts visited Detroit on May 26, 1917. I conducted them through the Aircraft Engine Experimental Department of the Packard company, and explained the development work that had been carried on there for 2 yr. They seemed to be very much pleased with the quality of the work and the general details of design of the Packard aircraft engine, and stated that it would no doubt be a very fine engine for certain kinds of work, but that its power-weight ratio was too great to make it of any real value in an up-to-date military airplane. The engine would develop about 235 hp., and without water or radiator weighed a little under 3½ lb. per hp. We had a very thorough discussion of the aircraft situation, and the commission gave us many valuable hints in connection with the latest developments in Europe. I realized that there was not a single firm in the United States working on aircraft engines that would be of any real value on the fighting line.

I read later that there were at that time about thirty-seven different kinds of aircraft engines being manufactured or experimented upon in England and some forty-six different kinds in France. This multiplicity of design not only made for high price and low production, but also caused great complication in the field, as it was next to impossible to keep on hand proper repair parts for all types of engines.

I discussed the situation with the president of the Packard Motor Car Co., who appreciated the need for a

standardized line of aircraft engines, and suggested that we communicate with Mr. Coffin. I left Detroit for Washington on May 27, in company with R. D. Chapin of the Hudson company. We had a conference with Messrs. Coffin, Deeds and Waldon. I pointed out the absolute impossibility of obtaining a large production of aircraft engines in this country if the various factories were left alone to go their own way in the designing of aircraft engines. I told them that if it was going to be necessary for the automobile industry to build a large number of aircraft engines they must be furnished with a proper standardized design, so that they would not have to waste any time in experimental work. I pointed out the fact that the Packard engine was too low powered and too heavy, but that this could easily be remedied by increasing the piston displacement and lowering the factor of safety. I explained that this engine had been designed to weigh under 4 lb. per hp. and run for the longest possible time without overhaul, and that it was the result of specifications put up to me by the Government about two years before, but that since then aircraft development had been rapid, with the result that conditions were entirely changed. I pointed out that the French and English commission had stated to me that a fighting airplane must be equipped with an engine of the lightest possible weight per horsepower, which meant that it must be designed with the lowest possible factor of safety that would serve satisfactorily for a reasonable length of time.

Designing the First Engine

After discussing the matter at some length, Mr. Deeds suggested that he would like to have me meet E. J. Hall. On May 29, Mr. Deeds, Mr. Hall and I got together, just before noon, at the New Willard Hotel, and went carefully into the situation so that we might make a joint report on the aircraft engine situation in this country promptly. By mid-afternoon Mr. Hall and I were ourselves laying down two views of a proposed eight-cylinder aircraft engine.

To get started promptly, we called Mr. Zimmerschied, who was then in charge of the Society's Washington office, and asked him to get us a draftsman and some drafting materials. He could not find a draftsman, but sent over his own drafting instruments. We purchased drafting tables and supplies, and were soon busy. I laid out a transverse section, and Mr. Hall a longitudinal one. We were very well informed on all engines manufactured in the United States and also a great many of the foreign makes, but we, of course, also wanted the latest information on British and French engines. We appealed to Major Souther of the Signal Corps, and he immediately put Charles King on the job of rounding up this information for us.

That evening Mr. Deeds called a session at the New Willard, at which members of the French commission were present. By this time Mr. Hall and I had specific questions that we wanted to ask, and they were answered quite fully by the French officials. The next morning Mr. Zimmerschied turned one of his volunteer helpers over to us, Mr. Schoonmaker of Pittsburgh. Like Mr. Hall and myself, Mr. Schoonmaker had done no drafting work for a number of years, but nevertheless he did not hesitate to take off his coat and go to work. I turned the drawing that I was making over to Mr. Schoonmaker, and proceeded to dictate a report to the Aircraft Production Board, which Mr. Hall and I had agreed on the night before. I reproduce this report below, as I believe it clearly sets forth our understanding of the situation at that time:

> At your request, we have made a careful study of the aircraft engine situation, and hasten to submit our report, as follows:
>
> To get this report in your hands promptly, we have condensed it as much as possible, and have covered the essentials only. In view of the fact that there are a number of good engines for training machines available, we have disregarded this type of engine, and we have confined our attention strictly to the high efficiency, low weight per horsepower type, such as is needed at the front.
>
> In order that the engines built by this country may be of any value when received at the front, it is, of course, absolutely necessary that their efficiency be brought up to, or a little beyond, the best now available in Europe. The French and English commissions have enabled us to obtain this information by answering our questions very clearly and completely. From information obtained from these gentlemen and from other sources, we believe that the Lorraine-Dietrich is the coming engine in Europe. This engine has not been built in large quantities as yet, but some thirty have been constructed and carefully tested out at sea level, and also at about 6000 ft. elevation.
>
> The important facts about this engine are as follows: Eight cylinders, 120-mm. bore by 170-mm. stroke; cylinders made of steel with water-jackets welded on. Engine is direct-driven and develops 250 hp. at 1500 r.p.m. and 270 hp. at 1700 r.p.m. The weight of the bare engine is 240 kg., or approximately 528 lb., while the weight of the engine complete, with radiator and water, is 305 kg., or 671 lb. There seems to be a reasonable doubt regarding the exact weight of the bare engine, as, while the French commission gave us the figure of 528 lb., information from other sources indicates a weight of 552 lb. Probably some intermediate figure is more nearly correct, but in any event the engine gives a horsepower for approximately 2 lb. of weight when figured at its maximum output of 270 hp.
>
> After obtaining this information and considering the matter very carefully, we next investigated the manner of testing such an engine, as we knew that an engine of this type could not be run at full power for long periods of time without developing serious trouble. Here again the French commission gave us valuable information. They stated that in using an engine of this type it is only run at full power for short periods of time, while climbing or fighting, and that at all other times it is run at speeds 200 to 300 r.p.m. slower. In view of the fact that the engine is built to run under these conditions it is, of course, necessary to test it under a similar condition, and they stated that when trying out a new model of engine it is their practice to mount a propeller which will just hold the engine down to maximum speed under full throttle. The engine is then run for 50 hr. in periods of 6 to 8 hr. each, but the engine is not run up to full speed for more than a total of 10 hr. during this entire period, nor is it run more than 30 min. at any single time under this condition. The other 40 hr. running is under throttled condition, turning the same propeller at 200 to 300 r.p.m. less than maximum speed.
>
> This information is of the utmost importance, as it enables us to reduce all factors of safety and makes possible the light weight per horsepower now being obtained in Europe. After securing this information, we immediately laid down a proposed engine, which we believe can be produced promptly in large quantities in this country. Built carefully out of proper materials, this engine will have approximately the following characteristics and be as good, or a little better, than the Lorraine-Dietrich, which is not as yet really available abroad. In laying down this engine we have, without

reserve, selected the best possible practice from both Europe and America. Practically all features of this engine have been absolutely proved out in America by experimental work and manufacturing experience in the Hall-Scott and Packard plants, and we are, therefore, willing to stake our reputations on this design unhesitatingly, provided we are allowed to see that our designs and specifications are followed absolutely.

The engine is to be of the eight-cylinder type, with cylinders set at an included angle of 45 deg. The cylinders are of the individual type, made out of steel forgings, with jackets welded on. The bore is 5 in. and the stroke 7 in., giving a piston displacement of 1100 cu. in. The crankshaft is of the five-bearing type, with all main bearings 2⅜ in. in diameter and all crankpin bearings 2¼ in. in diameter. The connecting-rods are of the I-beam straddle type. This engine is of the direct-driven type with a maximum speed of 1700 r.p.m. It will have a maximum output of 275 hp. at 1700 r.p.m. and will weigh 525 to 550 lb., but we feel very sure of the lower figure. It will have a gasoline economy of 0.50 lb. of fuel per hp.-hr. or better; it will have an oil economy of 0.04 lb. of oil per hp.-hr. or better. Complete with water and radiator, this engine will not weigh more than 675 lb., if a properly constructed radiator is used and placed high above the engine. To obtain the above mentioned weights, it will be necessary to use the fixed type of propeller-hub, which has been thoroughly proved out by Hall-Scott practice. It will also be necessary, as mentioned above, to use the very best material, workmanship and heat-treatment.

Complete detail and assembly drawings, as well as parts lists and material specifications, can be completed at the Packard factory under our direction in less than four weeks. We believe that a sample engine can also be completed in approximately six weeks, if money is used without stint. As soon as the drawings, specifications and a sample engine have been finished, complete information would, of course, be available, so that any high-grade manufacturer could either make parts for this engine or manufacture it complete.

In laying down this design, we have had in mind the extreme importance of interchangeability, as a well laid comprehensive program, which has for its base interchangeability of important parts, such as cylinders, will speed up output and reduce ultimate cost to an astonishing extent. Europe is suffering right now from lack of uniformity of design, but it is too late for them to change their plan. We, however, can take a leaf out of their book and start right.

In the design which we have laid down, the cylinder, for instance, can be used to make four, six, eight and twelve cylinder engines. As this is the most intricate part to make, immense facilities could be provided to produce them in large quantities for the use of many concerns who could manufacture the rest of the engine. Nearly all small parts, and numerous large and important ones, would also be interchangeable. This would not only speed up production, but would be of the utmost importance in connection with repairs and replacements. A full line of engines made according to this plan would be about as follows:

Type	Rated hp.	Maximum hp.	Weight, lb.	Weight per hp., lb.
4	110	135	375	2.7
6	165	205	490	2.3
8	225	275	535	1.9
12	335	410	710	1.7

Respectfully submitted,
(Signed) J. G. VINCENT.
(Signed) E. J. HALL.

The above report was finished on the afternoon of May 31, and we had at that time got the cross-section and longitudinal section drawings fairly well blocked out. About 3 p. m., Mr. Waldon telephoned Mr. Hall and me to bring our report and drawings over to General Squier's office in the Army and Navy Building. When we arrived we were promptly shown into the conference room, where a joint conference of the Army and Navy and Aircraft Production boards was in session, with Mr. Coffin in the chair. Mr. Coffin called for our report, and we asked Mr. Waldon to read it.

ACTUAL LAYOUT WORK STARTED

After the report was read we were asked to explain the drawings, which we did as quickly and clearly as possible. We, of course, explained that these drawings were only intended to show the general idea, and that we could, however, get layouts made quickly if our suggestions met with favor. We were immediately requested to go ahead with all possible haste and make good layouts. We wired to Detroit for two good layout men, and they arrived about noon, Friday, June 1. Messrs. Hall, Schoonmaker and I kept right ahead with our layouts, on which we were determining construction features. This allowed good layout men to go ahead with the finished layouts of settled construction. We all worked without stopping until Monday afternoon, June 4. By that time the layout men had finished good, accurate layouts of the longitudinal section, transverse section, rear elevation and camshaft assembly views of the eight-cylinder engine.

About the middle of the afternoon of June 4, Mr. Hall and I were again requested to go before the joint committee of the Army and Navy, with the Aircraft Production Board, to make a further report. We exhibited the finished drawings and went somewhat more into detail than had been possible at the previous meeting. After we had explained the drawings we left the conference with Mr. Deeds, who was just starting for Dayton. Mr. Deeds told us that it had been decided that we should build ten sample engines, five of the eight-cylinder size and five of the twelve-cylinder, and asked us to "go to it" and produce the first sample eight-cylinder engine at the earliest possible moment. He told us he had promised that we would finish the first sample eight-cylinder engine in seven weeks from that date. We immediately sent the layout men home to Detroit with instructions to complete the detail drawings of the long-time parts, such as cylinders and crankcase, immediately.

Mr. Hall went to Indianapolis that night and I went to New York, where I met Mr. Macauley the next morning and explained to him just what had taken place. Mr. Macauley and I returned to Washington on the morning of June 6, and immediately went into conference with Messrs. Deeds, Waldon and Hall. Mr. Deeds explained to Mr. Macauley the great advantage of standardizing a line of U. S. A. engines, and after a little thought Mr. Macauley not only agreed to this very radical step, but also to the loan of my services to the Government for a period of three months so that I might follow up the engineering work which had been started.

Mr. Deeds explained to Mr. Macauley that money had been appropriated to cover the cost of this development, but that he realized that to make good on the deliveries which he had promised I must have the right to order things quickly through commercial channels with which I was well acquainted. To this end he requested Mr. Macauley to arrange for the Packard Motor Car Co. to "finance the job," so to speak, or, in other words, to buy and pay for anything which I requested for the work, with the understanding that the Packard company would

render an accounting, and be reimbursed by the Government. Mr. Macauley agreed to do as requested, stating that this work would be put ahead of anything in the factory, and that I would have the "right of way," not only as to the services of my well-trained experimental organization, but the factory facilities also. This was the day on which the "U. S. standardized aircraft engine" idea was really settled.

As a matter of interest, I will state that Mr. Hall and I designated this line of engines as the U. S. A. standardized line, but a little later I believe Admiral Taylor "dubbed" it the "Liberty" engine in one of the Aircraft Board meetings, and this name took so well that we were forced to adopt it, and change all our titles on the drawings.

Mr. Hall and I left Washington Thursday noon, June 7, for Detroit, where we arrived on Friday morning. We went to the Packard factory and looked over the work on detail drawings which had been started. We found that O. E. Hunt had taken very prompt action, and already secured billets of steel from Cleveland out of which to make cylinders for the first engines. Mr. Hall spent the day going over various matters with me and left on the night boat for Cleveland to make arrangements to get crankshaft forgings for the first engine. These forgings, completely heat-treated, were produced in three days, Mr. Hall having given permission to "dig out" his dies.

I, of course, realized that to get the first engine quickly we must have detail drawings almost immediately, and I therefore called for volunteers from the various drafting departments of the Packard organization to work Saturday afternoon and Sunday. Every man volunteered, with the result that we had a very large force working Saturday afternoon and Sunday, and during this day and a half approximately 86 per cent of the detail drawings were finished on vellum, from which blue prints could be made. In other words, on the morning of June 11 I was enabled to get blue prints of 86 per cent of the parts, and I immediately began calling on various automobile and accessory manufacturers to rush through enough parts for a first sample eight-cylinder engine.

The crankcase upper and lower halves were, of course, long-time parts, and these drawihgs could not be finished in a day and a half. We did, however, succeed in getting them nearly enough completed by Wednesday, June 13, to enable us to take off preliminary prints. These preliminary prints enabled us to start pattern work and also a wood model of the engine. Vellum drawings of the upper and lower halves were finished on Friday, June 15, and good blueprints were put in the hands of the experimental pattern shop.

In the meantime, the pattern shop had been working night and day on the wood model, which they succeeded in finishing and shipping to Dr. Stratton at the Bureau of Standards on Saturday. By this time the vellum drawings on all the major parts, except those contained in the oil-pump assembly, had been completed, and enough parts for a sample engine ordered from various factories.

Assembling An Engineering Organization

While all this work was going on during the week ended June 16 the Aircraft Production Board was furnishing engineering offices at the Bureau of Standards, Washington, where space had been arranged for by Dr. Stratton. I left Detroit on Sunday, June 17, with a complete engineering organization, which had been drawn from various automobile factories, including the Cadillac, Dodge and Packard. Engineers were also sent from the Pierce-Arrow plant, and they met us at Washington. I arrived in Washington on Monday morning and immediately set to work getting settled in our new quarters at the Bureau of Standards.

In order to "put over" a job of this magnitude in a short time a tremendous amount of work must be accomplished quickly through the cooperation of a great many people who are peculiarly fitted by their training to do their particular parts without detailed supervision. At this stage the design was practically settled and the work of building samples was well under way. Everybody connected with the job continued to put forth his very best efforts, with the result that our first sample Liberty engine was delivered to the Bureau of Standards, Washington, on July 3, 1917. Additional samples of the eight-cylinder, also samples of the twelve-cylinder, followed quickly, and the first sample twelve-cylinder Liberty finished its first official 50-hr. run at 1.30 a. m., Aug. 25, 1917, having gone through this 50-hr. run in an elapsed time of only about 55 hr., thus breaking all records for tests of this kind. It is usual to run such tests in periods of 5 hr. each, two runs being made each day. In other words, it usually takes five or more days to complete such a test. This 50-hr. test was made under the supervision of Government Inspector Lynn Reynolds, and after finishing his very complete report of the test, he wrote the following foreword:

> The appended report is a survey of the main phases of the 50-hr. endurance test, maximum power curve calibration on electric dynamometer, and inspection of dismantled parts of U. S. A. twelve-cylinder aircraft engine No. 1, which were made under the supervision of the Equipment Division, Signal Corps, at the Packard factory, Detroit, Mich., Aug. 22 to 25, 1917.
>
> A consideration of the data collected, will, we believe, show that the fundamental construction is such that very satisfactory service with a long life and a high order of efficiency will be given by this powerplant, and that the design has passed from the experimental stage, into the field of proved engines.

All the Government officials who had been following this job carefully realized that while no doubt a great deal of detail work remained to be done, this test conclusively proved that we had an engine design capable of being produced in large quantities in this country, and that it would compare favorably with the best designs that had been developed in Europe. Acting on this belief, all possible haste was made in cleaning up the drawings, and a complete set of drawings of both the eight and twelve cylinder designs were turned over to Lieutenant Emmons, who was in charge of engine production, about Oct. 1, 1917. It was, of course, understood that many detail changes would have to be made in these drawings during the early stages of manufacture.

The First Engine Completed

After careful consideration of reports from abroad it was decided to put the twelve-cylinder engine into production, and hold the eight-cylinder back, as all demands from abroad called for around 400 hp. The first "production" twelve-cylinder engine was delivered at McCook Field, Dayton, Ohio, on Thanksgiving Day, 1917, but it should be borne in mind that this engine was only partially made from production tools. In fact, the first several hundred engines were made more or less by hand to

get out a reasonable quantity at the earliest possible date, and thus permit extensive tryouts under actual flying conditions.

During the time that this work was going on, Captains Clark and Marmon returned from Europe, and after going over the Liberty engine carefully in the light of what they had learned, agreed that we had been very wise in developing the Liberty engine, because, in their opinion, an engine of 400 hp. was essential for types of machines that it had been decided we should manufacture, and they stated that no proved 400-hp. engine existed in Europe.

Spurred on by this encouraging information, every one concerned put forth his best efforts to get into quantity quality production at the earliest possible date. From this point on the facts are pretty generally known. As soon as the necessary samples could be shipped to Europe they were carefully tried out under actual flying conditions by our allies. First England, and then France and Italy, accepted the engine, and began to negotiate for the purchase of these twelve-cylinder Liberty engines for installation in their planes. Unfortunately, our own plane production was considerably delayed, not so much on account of the plane itself, but by the fact that we did not have in this country the necessary instruments and armament to equip the planes. In other words, the design of the DeHaviland-Four could have been finally settled in November or December, 1917, had information been available as regards all the instruments and armament, but this information did not become available until late in March, 1918. As soon as this information was available the DeHaviland-Four design was quickly cleaned up, and I believe that a real record was made in getting it into production after that time.

What the Tests Revealed

As soon as these planes became available they were extensively tested both in this country and abroad, with the result that numerous minor faults were developed, which had to be corrected. The extensive test work of the Liberty-DeHaviland combination also developed several shortcomings in the Liberty engine, which had to be corrected after production was fairly well under way in one plant. In this connection, however, it is interesting to note that the correction of none of these difficulties involved any radical change in the basic design.

It is now a well-known fact that the DeHaviland plane equipped with the Liberty-Twelve did wonderful work at the front, and that it was considered the best all-round plane available at the time the armistice was signed. It is also a significant fact that England, France and Italy were taking deliveries of these engines just as fast as they could get them, and installing them in their

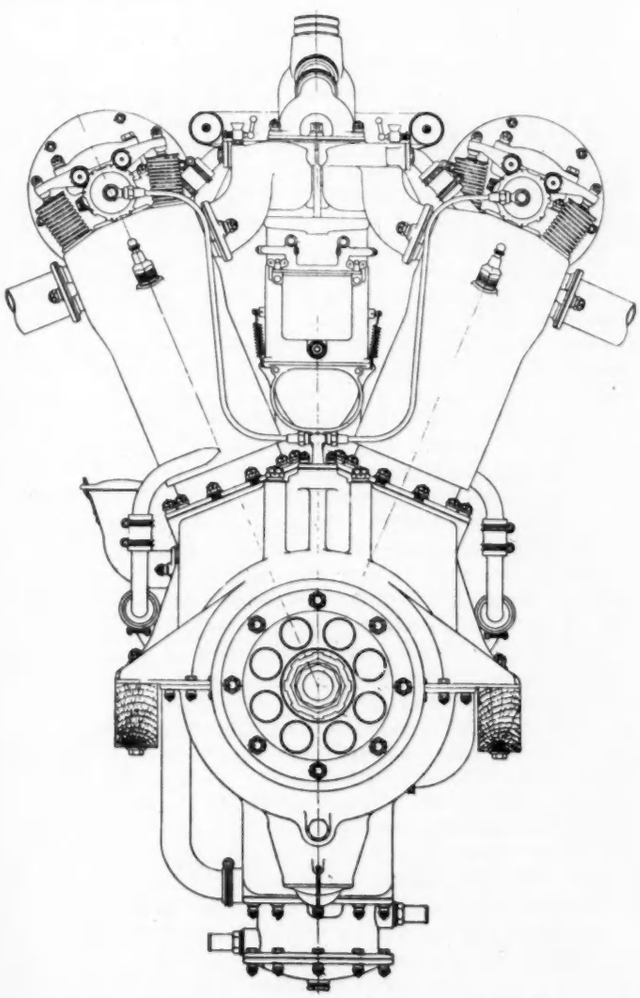


Fig. 1—Front Elevation of the Liberty-Twelve Engine

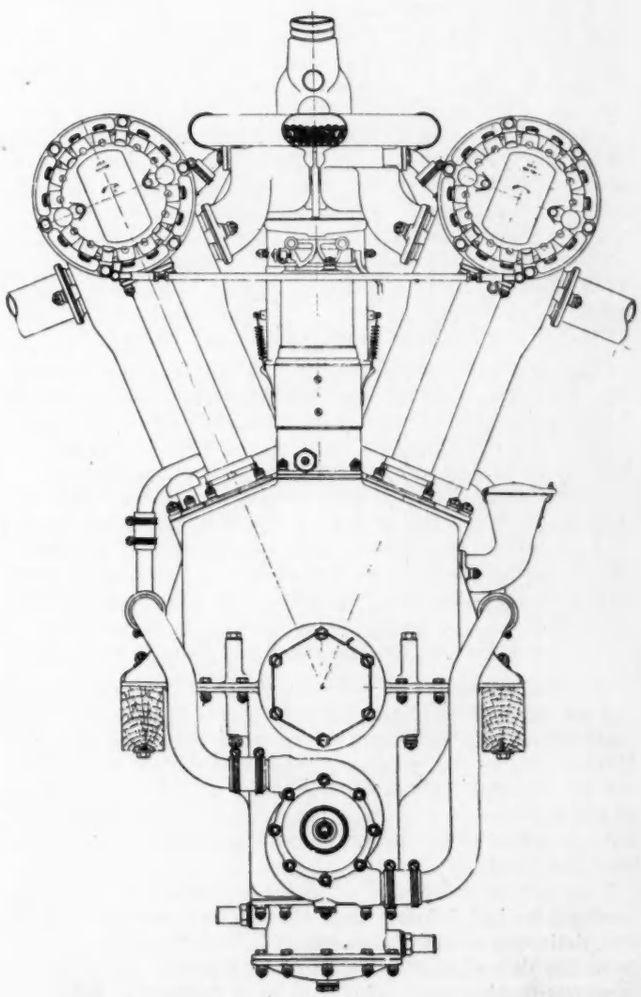


Fig. 2—Rear Elevation of the Liberty-Twelve Engine

various types of observation, two-seater fighting, day bombing and night bombing machines.

The fact that no tried 400-hp. engine existed in Europe was one good reason for developing the Liberty engine, but other equally good reasons existed. The engines developed by our allies had been built under extreme pressure. There were so many different kinds that none of them was made in any great quantities. Probably the two best foreign engines at that time were the Rolls-Royce and the Hispano-Suiza. According to information received at that time, the Rolls-Royce developed about 350 to 375 hp., and was recognized as probably the best large engine available for our allies. It was, however, developed for European manufacture in small quantities, and was composed of a great many intricate parts, which would be very hard to manufacture in quantity under American production conditions. For example, many of the important forgings would have had to be made much better than had been our practice in this country. The Liberty engine was designed to be as reliable as Rolls-Royce, develop a little more power, be a little lighter per horsepower and cost about one-half as much. These aims have all been accomplished.

The Hispano-Suiza was a smaller engine, and as it was already in production in this country, and continued to be produced in increasing quantities, it need not be considered in this discussion.

The Lorraine-Dietrich eight-cylinder engine, which it will be remembered was held up to Mr. Hall and me as the coming aircraft engine in Europe, did not come through the experimental stage as fast as had been anticipated. While Captains Clark and Marmon were in Europe they examined both eight and twelve cylinder models of this engine, but upon their return stated that it had not yet gone into quantity production, and as nearly as they could determine these engines were still in the experimental stage. Our Government had for months a standing order to ship one of the twelve-cylinder Lorraine-Dietrich engines to us, but it was never received. It is obvious, therefore, that it would have been a great mistake to depend on putting either of these Lorraine-Dietrich engines into production in the United States.

The only other allied engine that looked at all interesting was the Bugatti, and arrangements were made to bring a sample of this engine to America, so that it might be put into production. As was to be expected, it had to be entirely redesigned for American methods of manufacture, with the result that it was just getting into production when the armistice was signed. This engine was designed for a special type of service and can never be as light per horsepower as the Liberty. It may, however, have distinct military value for certain kinds of work.

A Standardized Line of Engines

To sum up what has been accomplished by the designing of the standardized Liberty aircraft engine, I will state that this development made it possible for the United States to produce large quantities of 400 to 420-hp. reliable light-weight aircraft engines. Handling of the maintenance problem was greatly facilitated, with but one set of repair parts for the vast number of engines manufactured.

I am not in possession of exact information regarding production, but I know that the first production engine was delivered to the Government in less than six months from the date that Mr. Hall and I turned in our original recommendation, and within a year from the date our recommendation was made some five or six large companies were in quantity production, and the output was increasing steadily day by day.

Had the war gone on for a few more months, we would also have been producing the 280 to 300-hp. Liberty-Eight in large quantities for single-seater fighting or chasse machines. To take care of the maintenance work on these eight-cylinder engines, it would have been necessary to put into stock only some twelve additional parts, as the eight-cylinder parts are interchangeable with the twelve-cylinder, except as to a few special parts such as the crankcase, crankshaft and the like.

An important advantage of the standardized line of engines, which is ordinarily overlooked, is the matter of installation in planes. To be a good job, all airplanes must be designed around the engine and equipment. Every different type of engine presents many new installation difficulties. We have worked out a standard form of installation for the standardized line of Liberty engines, so that we can give a plane designer definite information as to the engine tachometer, the gasoline system, the oil system, cooling system, the spark throttle and altitude control system, and many other details too numerous to mention.

I have talked with many experts who have been sent over by our allies, and all who have had practical experience at the front state emphatically that the most important thing about a military airplane is to have it reliable, and they, therefore, agree with me that it is very important to have all the systems standardized as outlined above so that the troubles can be worked out of them. They have stated to me that it has never been possible to work out good standardized systems abroad, on account of the fact that they have had so many different kinds of engines to install. Due to this fact, most of their installations have been more or less of a makeshift, and a very large percentage of their failures has been due to failures of some part of these systems, rather than to the engine or plane proper.

I hope that I have made the matter of standardization clear, as I consider it of the utmost importance, but I do not want to be understood as advocating that the Government use only one or two kinds of engines during peace time. The standardized Liberty aircraft engine was designed to meet an actual emergency, and I believe that everybody who is familiar with the facts, will agree that it was a very wise move. On the other hand, it would greatly retard development if the Government did not give careful and unprejudiced consideration to all designs submitted during peace times. If there is to be any real progress in the development of aircraft engines, airplanes or airplane equipment, however, it must be brought about by the cooperation of engineers and proper officials of our Government.

At the present time, the Engineering Division of the Bureau of Aircraft Production and the Technical Section of the Department of Military Aeronautics are being merged into one peace-time organization, which will probably be known as the Technical Section of the Department of Military Aeronautics. This reorganization is being carried out under the direction of Col. T. H. Bane of the Air Service, whom I personally know to be well fitted for the job, on account of his long training in the army, his knowledge of military aeronautics and his unusual broad-mindedness and impartiality.

The Technical Section of the Department of Military Aeronautics is a mammoth bureau of information, having on file at the present time a complete record of the present

state of the art, not only in this country but in all important foreign countries as well. In addition to serving as a bureau of information, this section, through its officers, acts in an advisory capacity to engineers, as critic of designs or sample machines, and, last but not least, as an experimental organization to test out all designs which are submitted. By cooperating with this department, all engineers may secure exactly the same data and advice, and be sure that their equipment will be tested in an unbiased, as well as in a standardized, way. In other words, all engineers will have exactly the same chance, and may be informed beforehand as to just what tests their equipment will have to pass through.

If the Department of Military Aeronautics is given proper support, as it must be if we are to remain prepared in our air service, the Government will be in a position to go into production quickly in any emergency, because the Technical Section will have a complete record of all tests, and will, therefore, be able to select the best equipment of each kind; and, furthermore, it will be in possession of the necessary drawings, specifications, etc., so that in such emergency there will be no necessity for an experimental stage.

In closing this chapter of my paper, I want to urge all engineers who are interested in aeronautics to cooperate with the Technical Section of the Department of Military Aeronautics, and work for the maintenance of a permanent technical department, in connection with our Air Service, so that we may never again be caught in the pitiful condition that existed in the early part of 1917.

Figs. 1 to 8 inclusive are all representative of the Liberty twelve-cylinder aircraft engine as it was being produced at the time the armistice was signed. Figs. 9 to 13 inclusive show certain alterations in the carbureter and intake header construction, which I will refer to and describe later. I will now take up the important elements of the engine and endeavor to point out the reasons for the design selected, as well as the results obtained.

Crankshaft

Figs. 4 and 5 clearly indicate the general construction of the conventional type of seven-bearing crankshaft. This type was selected because the comparatively large bore and stroke of the engine made it practically impossible to consider any less number of bearings. No counterweights were considered, because the engine is of the direct-drive type, and not intended to run over 1800 r.p.m. At this speed the main bearing pressures, due to centrifugal force, are not excessive. All main bearings, except the front one, are of the same length, which, of course, results in the bearing pressures being highest on the center bearing. Conservative design would have dictated a longer center bearing, but as this would have lengthened the engine and added some weight, we decided against it, as calculations and experience indicated that it was not absolutely necessary. Although this center bearing actually showed more wear in service than any of the others, it was never a source of trouble, as the wear was not excessive. From my experience with these engines, I would make the same decision again under the same circumstances, but would lengthen the bearing about 50 per cent, if I were designing an engine for commercial aviation. In this connection I will also state that for a commercial aviation engine, I would make all main bearing shells ¼ in. thick, instead of 3/16 in., as in the case of the Liberty.

The crankshaft main bearing journals are all 2⅝ in. in diameter and the crankpins 2⅜ in. The crankshaft cheeks, as originally designed, were the weakest point, and when we began to get into quantity production, small variations in material and heat-treatment occasionally resulted in a broken shaft, sometimes within a few hours and sometimes after from 50 to 100 hr. use. It was, of course, impossible to make the cheeks any thicker, and it was, therefore, decided to widen them to take the shape shown in Fig. 4.

So far as I am aware, no crankshafts of the revised design were ever broken, with the exception of the occasional shaft that contained a flaw, and these usually let go before the engine had passed its manufacturer's test. It is my belief that the crankshaft as strengthened is an entirely practical and satisfactory design for this type and power of engine.

Connecting-Rods

The design of connecting-rods and connecting-rod big end bearings, as originally specified, were on the light side, and while the connecting-rods themselves would stand up indefinitely, if made out of the best material with the best heat-treatment, the least variation would result in trouble. It was, therefore, decided to thicken all sections about 1/32 in., and while this added weight to the engine, it made a thoroughly practical manufacturing proposition.

One of the sources of trouble with the original design was sharp corners under the connecting-rod bolt heads, and this was generously filleted in the redesign. The trouble with the connecting-rod bearings was that they were too thin, with the result that they went out of shape under heavy load, and the continual distortion would crack the babbitt. These bearings would not burn out or break, but the babbitt would simply disintegrate, with the result that when the engine was taken down after 50-hr. use, the bearings would be in bad shape, and would all have to be replaced. This trouble was entirely overcome by increasing the thickness so that the thinnest portion under the straddle-rod forks was 9/32 in. thick.

The connecting-rods and connecting-rod big-end bearings as finally proved out and standardized, gave a uniformly satisfactory result, and I would not know how to improve them if called upon to do so at this time. We carried out a great many experiments at McCook Field with various kinds of V-type connecting-rods, including the so-called "marine-type," such as is used on the 300-hp. Hispano-Suiza, and the so-called "articulated type," such as is used on the Rolls-Royce. Both of these types can be made perfectly satisfactory, but we could not determine that they were any better than the so-called "straddle-rod type," as standardized for use on the Liberty. The connecting-rod piston-pin bushing, with its splash lubrication, proved entirely satisfactory, which seems to indicate that there is no necessity for carrying pressure oil to the piston-pin.

The connecting-rod length to stroke ratio is 1.71 to 1. This proved satisfactory but I would not recommend designing an aircraft engine with any lower ratio.

Pistons

The die-cast aluminum-alloy piston design, as originally laid down, proved very satisfactory, and was never changed. This piston design was originally dictated by Mr. Hall's experience, as he had proved by extensive experimental work, the value of a very thick head and

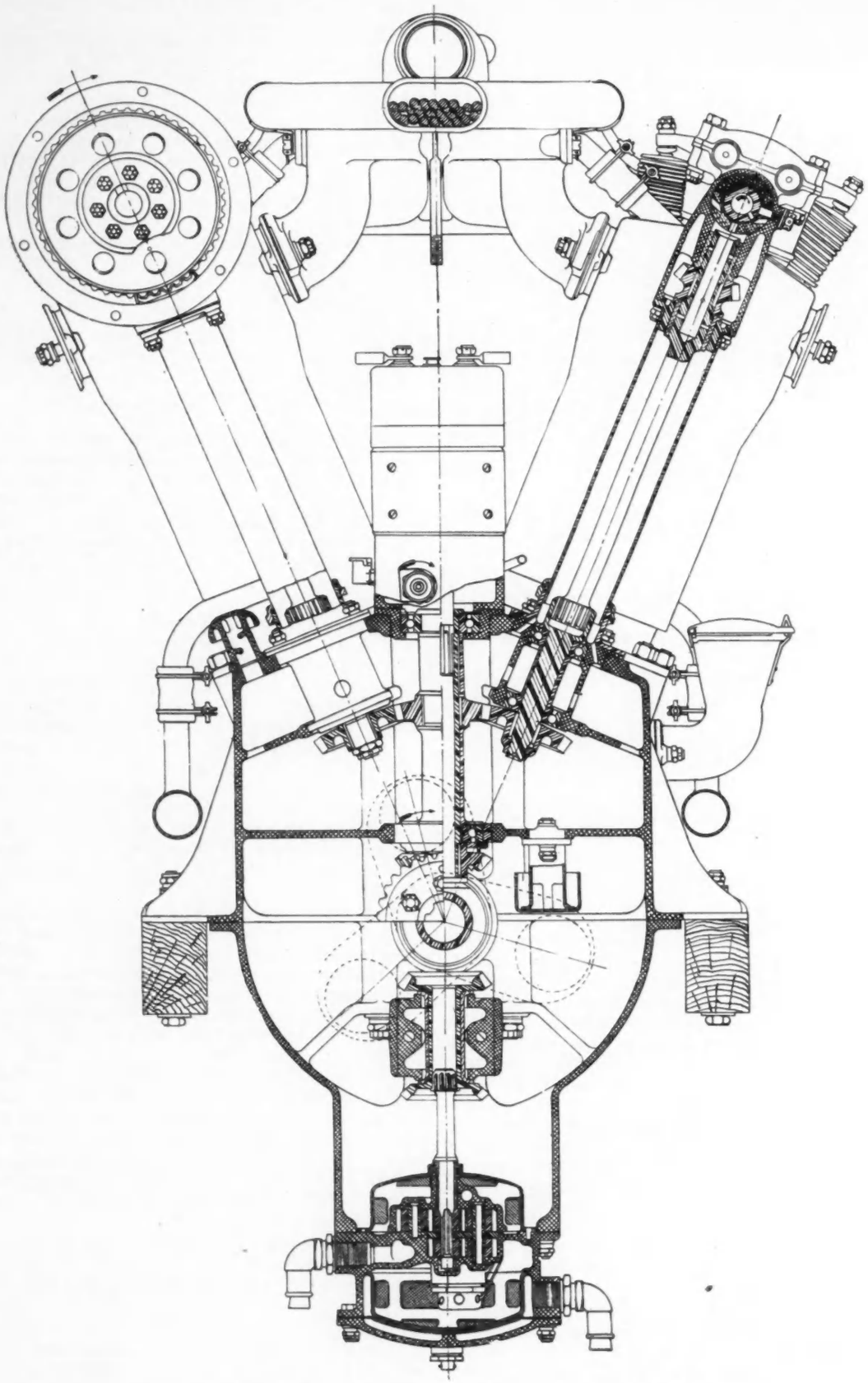


FIG. 3—SECTIONAL REAR ELEVATION SHOWING TIMING-GEAR TRAIN

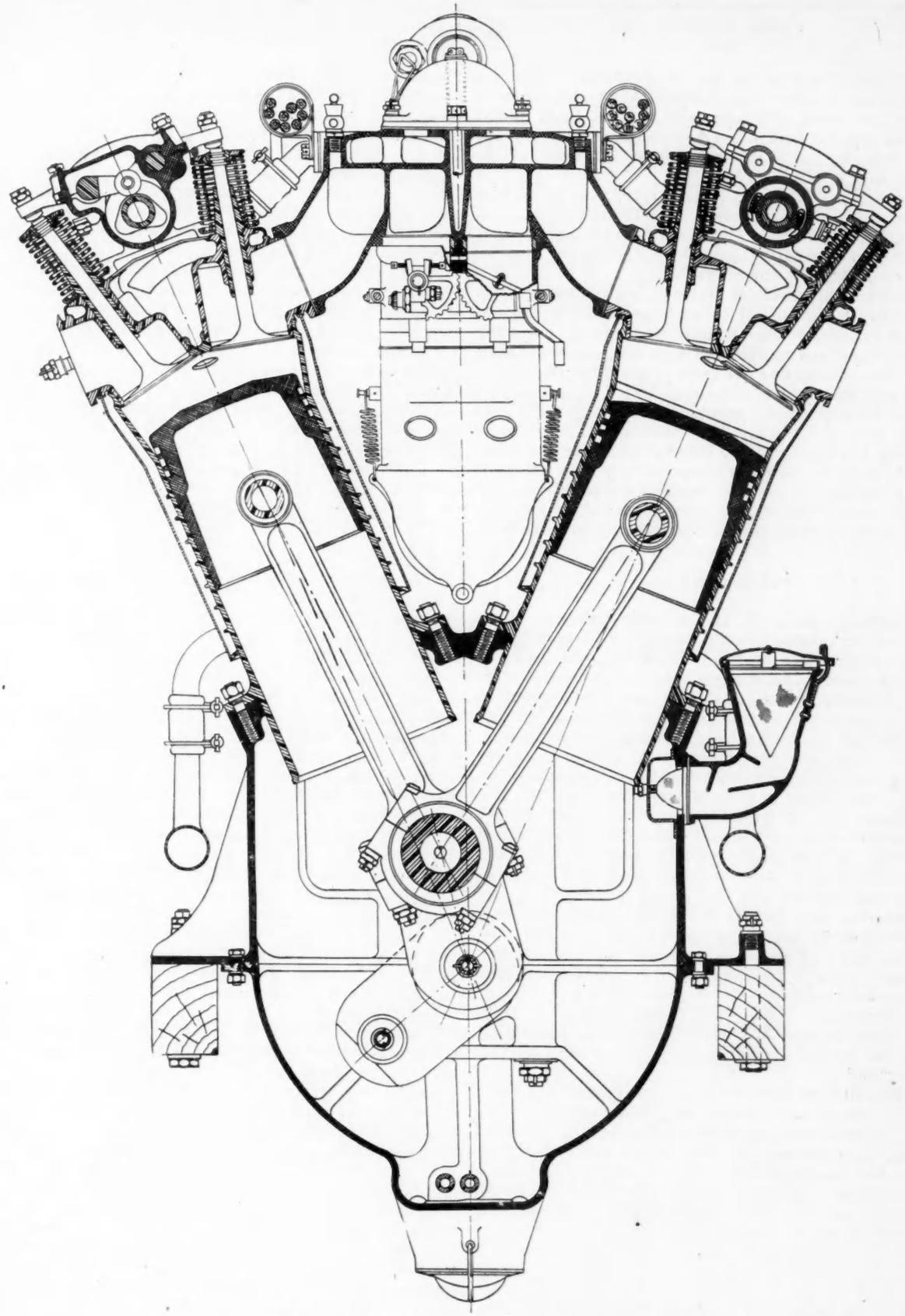


FIG. 4—TRANSVERSE SECTION THROUGH CYLINDERS

tapered piston wall increasing in thickness toward the top, in order to be as thick back of the piston-rings as through the head. The purpose of this thick piston head and tapered wall is, of course, to provide for the proper transfer of heat from the piston head to the cylinder wall.

The piston-pin is of the floating type, held in position by aluminum washers pressed into the piston at each side. This construction proved to be very satisfactory and prevented the usual trouble of cotter-pins and set screws dropping into the crankcase.

We had a little trouble at first with the pistons scoring, because they were too soft to work satisfactorily against the steel cylinder. This trouble was quickly cured by making the pistons harder and watching the heat-treatment of the cylinders to get them of a uniform hardness, though still machinable.

Fig. 4 shows the high-compression piston giving a compression ratio of 5.4 to 1. The low-compression piston is flat on top but has the same bearing length as the high-compression type. The low-compression piston was used for all navy engines, as they work at comparatively low altitude, and the high-compression for all army engines, as they were intended for use principally at high altitude.

Propeller-Hub

As originally designed, the propeller-hub was to be put on the crankshaft permanently, as it was feared that a detachable hub would give trouble in an engine of such large power. This design, however, was contrary to foreign practice, and so much pressure was brought to bear in favor of the detachable hub that the design was changed before the engine was ordered into production.

Fig. 5 shows the propeller-hub as finally designed, including the propeller-hub key running clear out to the rear end. The taper is 1 to 12. The propeller-hub key as originally put into production was short and did not extend within 1 in. of the rear end. This construction gave trouble, in that the hub would freeze on the shaft, making it hard to remove and impossible to replace without filing and lapping.

This trouble was largely overcome and a practical result obtained by extending the key clear to the rear end of the hub and grinding the shaft and hub so that all the draw came at the rear end. By this I mean that the tapers were made so that they did not exactly match, and the front end of the shaft would be perhaps 0.001 in. loose with the rear end drawn up tight. This simply insured that the hub would be absolutely tight at its big or driving end.

The offset hub, as shown in Fig. 5, was really an afterthought to allow room for shutters in front of the radiator, but it proved more satisfactory than the conventional type, due, it is believed, to the reinforcing of the rear flange by the hub extension. The diameters of the propeller-hub flanges and bolt-circle, as well as the thickness of the propeller-hub, proved entirely adequate for the horsepower output of the engine.

Crankcase

As shown in Figs. 1, 2, 3, 4 and 5, the crankcase is of the deep box-section type; the upper and lower halves being lapped together and firmly anchored to each other by numerous bolts around the flanges, as well as long through-bolts on each side of all main bearings. The design of the individual steel cylinders made it possible to extend them down into the crankcase, thus greatly increasing the possible depth and strength of the crankcase, and at the same time making it possible to reduce the included angle between the two rows of cylinders to 45 deg. As is clearly indicated, the main bearings are carried between the upper and lower halves. In my opinion, the design of this crankcase had a great deal to do with the satisfactory operation of the Liberty engine, and I know that no other type could be designed anything like as light and still stand up.

After the Liberty engine had been in production for some months, a well-known English engine expert came to America, and in carefully going over the design of the engine with me, he asked where we got our information as to the design of the crankcase. After I explained its advantages, he told me that they were just then beginning to realize the value of the box-section type of crankcase in England, and that experiments carried out recently had proved to them that this type with the bearings carried between halves is a very great improvement over any other design which they had used. The engine bed flange design, including the number of bolts, form of ribbing, etc., has proved entirely satisfactory.

Cylinders

The individual cylinder design was, of course, originally selected on account of the necessity for a seven-bearing crankshaft, but while the design was being laid down it was recognized that the individual design was right for several other reasons. This design made it possible to machine pilots to extend into the crankcase, thus increasing the depth of the crankcase and making it possible to narrow up the angle without weakening the crankcase too much at the center or having the cylinder flanges overlap. The steel cylinders as selected for this make for more simple machining and easier application of the steel water-jacket. This design also makes for easy assembling and dismantling of the engine, and therefore facilitates manufacture as well as maintenance. It is very convenient to be able to remove a damaged cylinder quickly without disturbing the remainder of the engine and without removing it from the plane. The design of steel cylinder is shown in Figs. 1, 4 and 5. In my opinion the steel cylinder is the lightest that can be designed, and its construction provides for the best possible valve cooling. In spite of the fact that the Liberty valve is 2½ in. in diameter in the clear, it cools very satisfactorily, and I have seen any number of engines taken down after 100 hr. flying, with the valves still in good, serviceable condition. Owing to the shape of the steel water-jacket around the spark-plug, considerable difficulty was experienced in producing this stamping, but dies were finally devised which produced a very perfect result with the minimum of scrap.

One of the big manufacturing problems in connection with the steel cylinder was to secure hollow forgings of the proper material, which would provide for the minimum removal of material in machining. This job was submitted to two different companies, the Ford Motor Co., Detroit, and the J. G. Brill Co., Philadelphia. Both worked out a thoroughly satisfactory and economical forging. The Ford company developed a process to make this forging from steel tubing, while the J. G. Brill Co. used a process to make the forgings from billets. One of the difficulties in producing this forging was the fact that its flange is located several inches from the lower end. It is my belief that both companies finally used the same process to produce this flange, consisting of an

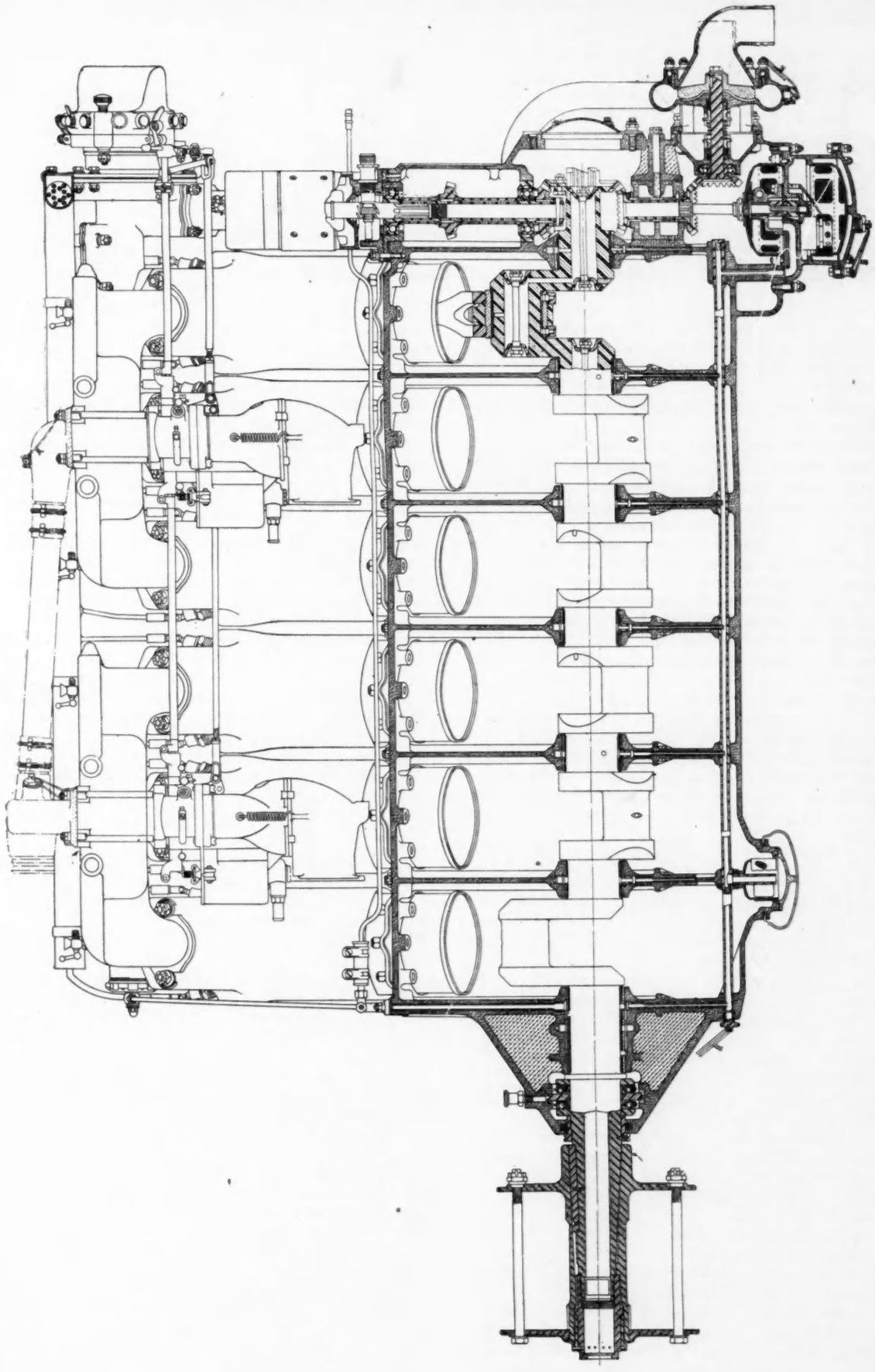


Fig. 5—Longitudinal Sectional Elevation

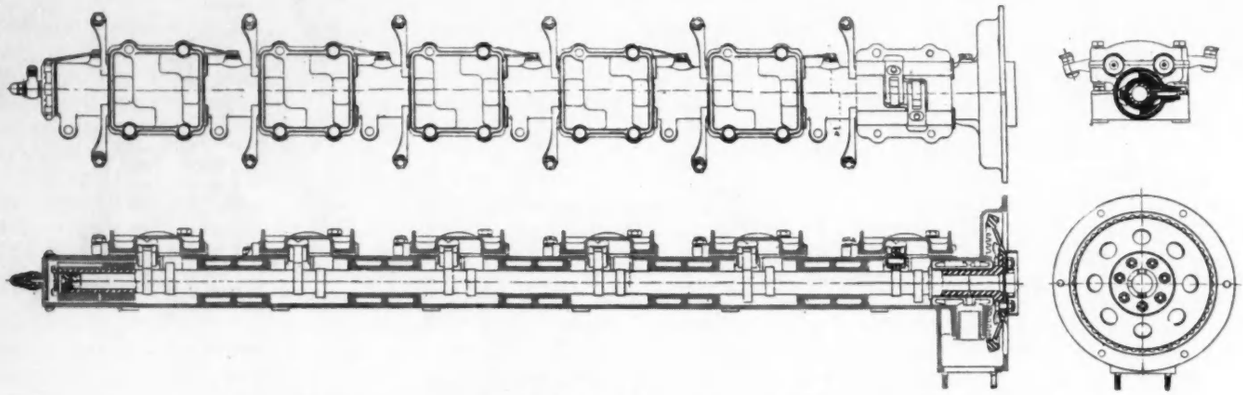


FIG. 6—PLAN AND SECTIONAL ELEVATION VIEWS OF THE CAMSHAFT AND HOUSING ASSEMBLY

upsetting operation, with the bore properly reinforced by a pilot.

The valve-port cages are machined from separate forgings and welded on, the camshaft housing support bosses being machined as an integral part of these ports. The design is such as to provide water-cooling for almost the entire length of the exhaust-valve-stem guide. Proper welding on of the steel jackets proved to be simply a matter of practice, to get a good job, and girls were used largely for performing this operation. The only trouble that I have ever heard of in connection with these cylinders was an occasional leak in the water-jackets, which usually occurred at the top of the jacket. This trouble would not occur frequently enough to be of any great importance, but we carried on extensive experimental work in an endeavor to find out what caused it, and came to the conclusion that it was caused by the flexing of the jacket, due to slight distortion of the cylinder head under the force of the explosion. If this is a correct deduction, the trouble could be cured in two ways, one being to put a positive tie between the valve ports and the other to thicken the cylinder-head, say 1/16 in.

CAMSHAFT HOUSING

The camshaft and housing assembly, as well as the valve rocker-arms, are clearly shown in Fig. 6. This construction proved to be very satisfactory, as it is positive in operation, practically never gives trouble, is quite easy to assemble and disassemble, and throws very little oil. This is the only type of valve-operating mechanism that has given real satisfaction in connection with V-type engines having steel cylinders and exposed valve-springs. It is, of course, a much simpler problem to work out a valve-operating mechanism for cast-in-block engines like the Hispano-Suiza, where the entire valve mechanism is covered and therefore oil-tight.

The arrangement of the driving gears is very clearly indicated in Figs. 3 and 5. This arrangement of gearing proved very satisfactory after we had overcome the initial troubles, due to bad design, such as lack of proper fillets, metal being cut down too thin under the teeth, etc. During the early manufacture there was a tendency to make these gears too hard.

Some trouble was experienced with the meshing of the bevel gears in the early stages of manufacture, due to the expansion of the crankcase and crankshaft under heat. This trouble was finally overcome by working out the proper clearances and then shimming to that clearance.

The latest Mercedes engines contain a very great improvement, however, at this point. The bevel gear is splined on the crankshaft with a sliding fit, and a separate thrust is provided to locate the gear and determine its mesh. This does away with all variations due to expansion and contraction, and is therefore a great improvement.

Before we had extensive experience with these engines it was predicted that we would have a great deal of trouble from breakage, due to crankshaft vibration. I know that the Rolls-Royce Company did have serious trouble of this kind, and was forced to put a compensating spring drive on the crankshaft gear. I believe that we would have had the same trouble with the Liberty, had the cylinders been placed at an angle of 60 deg., but due to the 45-deg. angle the periodic vibration seems to be broken up to a marked degree.

This could, of course, be proved only by building a sample 60-deg. Liberty, but I firmly believe that the 45-deg. allowed us to get by at this point with the simple light construction.

LUBRICATION

The double-deck oil-pump and pressed-in oil manifolds are shown in Fig. 5. The crankcase is of the dry type, all oil being returned to an outside tank, cooled, and then pumped to the bearings under pressure.

As originally designed, the so-called scupper type of oiling system was provided for the connecting-rod big end bearings. With this system the crank cheeks are not drilled, but part of the oil which works out of the ends of the main bearings is caught by scuppers or scoops and conducted into the large drilled hole through the crankpin. This system has some very desirable features, among which are simplicity and superior oil economy, and under ordinary conditions it works extremely well, but unfortunately it has one serious drawback. Due to the fact that the large holes through the crankpins are open, all of the oil drains out when the engine is stopped, except in those crankpins which are near the bottom. This does not make much difference in warm weather, as the oil will quickly flow to the ends of the main bearings and be caught by the scuppers when the engine is started, but under cold-weather conditions trouble results, and bearings are liable to be burned out, particularly if the throttle is opened quickly after starting. Since this scupper-feed oil system had been criticized by foreign engineers, we lost no time in changing over to the full pressure-feed system as soon as the first trouble showed up. Comparatively few

engines were manufactured with the scupper feed, and so far as possible all light crankshaft scupper-fed engines were kept in this country.

After adopting the full pressure-feed system no further lubrication trouble was encountered, with the exception of over-oiling of the cylinder and fouling of plugs at high altitudes. This trouble was very largely overcome by drilling a hole in the by-pass valve of such size as to lower the oil pressure to about 3 to 7 lb. under idling conditions, and still provide 30 to 40 lb. of oil pressure under full load. This device was entirely satisfactory, with the exception that it varied somewhat with different kinds of oil.

At the time the armistice was signed we were experimenting in the air with various kinds of devices interconnected with the throttle to control the oil pressure positively. This is a comparatively easy thing to design, but we wanted to accomplish the result without making any changes in the basic parts of the Liberty engine. Although this device never got into production, I feel that the principle of positively controlling the oil pressure is correct and should be a part of any aircraft engine design.

Cooling System

The construction of the water-pump is clearly shown in Fig. 5. One of the important features of this pump is the automatic spring take-up of the two stuffing-boxes, one of which seals the oil in the engine and the other the water in the pump. This construction proved very satisfactory. From an installation point of view, the water-pump is located in a rather bad place, and experience seems to indicate that the best practical place to locate the water-pump is at the bottom of the crankcase near the rear end, in a vertical position, as on the Hispano-Suiza aircraft engine. Nothing which ever has to be got at should be placed on the rear end of an aircraft engine, as it is often desirable to locate the engine just in front of a permanent bulkhead. To have located the water-pump as suggested in the Liberty engine it would, of course, have been necessary to have a different arrangement of the oil-pump. The Hispano-Suiza oil-pump is a very satisfactory arrangement, but I prefer that the oil-pump be placed so that it can be got at from the bottom or one side of the crankcase, without disturbing the water-pump or any other accessory.

Many rumors have been circulated that the Liberty engine is hard to cool, but this is not and never was a fact. We did have two difficulties in connection with cooling the Liberty engine, one being that of the difficulty which we had in obtaining good tubular radiators, and the other that involved in working a 400-hp. radiator into the design of a plane which had originally been laid out for 240 hp. We were handicapped by not knowing just how much radiation to provide, as there is a great deal of difference between cooling an engine on the ground and at 10,000 or 15,000 ft.

We finally adopted the British practice on radiators, as follows: All radiators to be of the tubular type with the ratio between the inside diameter of the tube and its length 1 to 12 desired, and from 1 to 10 to 1 to 14 permissible; the size of the radiator to be determined by the

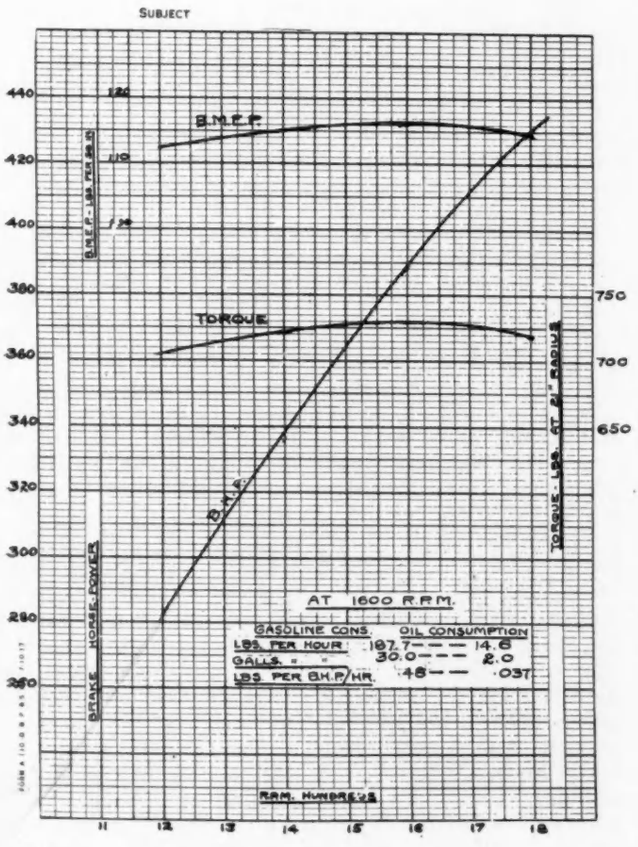


Fig. 7—Well Worked-in Engine

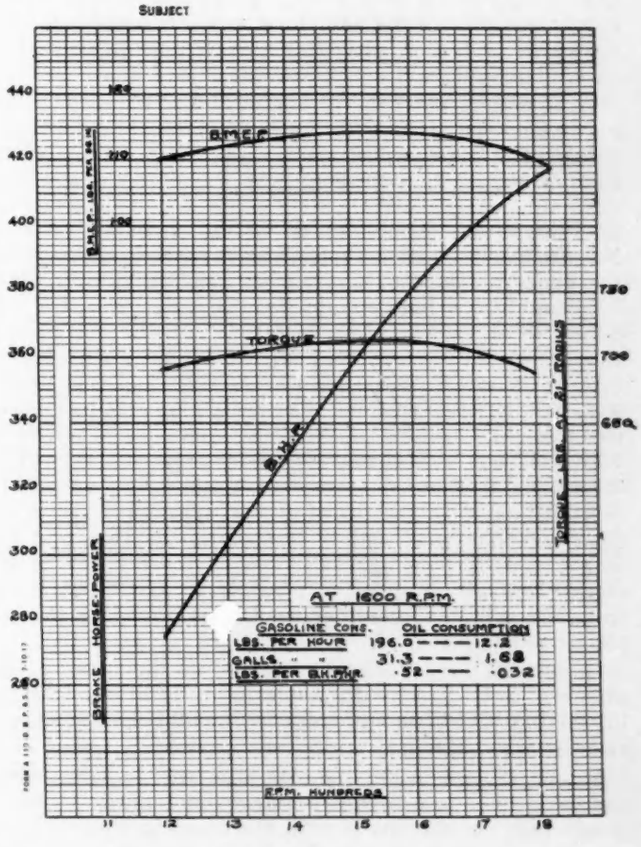


Fig. 8—As Delivered by Builder

Average Characteristic Performance Curves of Twelve-Cylinder Liberty Engine

horsepower output on the climb, 0.7 sq. ft. of wetted surface per hp. output being the desired figure. The area of the wetted surface is determined by calculating the outside surface of the tubes, nothing being deducted for the short space taken up at each end by solder:

$$\frac{\pi d l n}{144p} = 0.7$$

Where d = outside diameter of tube in inches
l = length of the tube in inches
n = the number of tubes
p = horsepower on the climb

This formula has been extensively used, and a radiator designed in accordance with it will give perfect satisfaction on any well-designed aircraft engine, provided the radiator is well made, properly located, and the air flow through it is not badly choked by obstructions.

For military work, shutters must be provided in front of the radiator, so that the pilot can close off the cold air and regulate the temperatures at high altitudes, particularly when gliding in cold weather.

Ignition

Figs. 2 and 5 show the arrangement of the ignition generator, as well as the ignition heads of the Liberty generator type of ignition. The small 10-amp.-hr. battery used in connection with this system can be located in any convenient place about the plane, and the double ignition switch is, of course, placed at a convenient point on the instrument-board.

At the time the Liberty engine was designed, so far as we knew no reliable light-weight twelve-cylinder magnetos were in existence, and we did not want to follow the foreign practice of using four six-cylinder magnetos, not only because of their weight but also on account of the weight and complications of the necessary drives. Mr. Hall and I had both had extensive experience with the generator type of ignition on aviation engines, and knowing that a light-weight reliable outfit could be secured, we deliberately incorporated it in the design, although we anticipated that we would meet with stubborn resistance from people who had not had experience with this type of ignition. The design, as originally laid down for this engine, proved to be exceedingly satisfactory, and very few changes were made during the early experimental stages.

As indicated in the drawings, an ignition distributor head complete with coil is located at the rear end of each camshaft housing; each one of these heads is so cross-wired as to make it possible to secure ignition in twelve cylinders on either head, thus providing a complete double system.

One of the very desirable features of the Liberty engine which is directly traceable to its ignition, is ease in starting, it only being necessary to pull the engine over very slowly to start it.

My experience would indicate that with a large-bore engine it is much better to start by pulling it over slowly than on the spark with the starting magneto or vibrator. I believe this is due to the fact that to start on the spark it is necessary to have the mixture just right and on the rich side, and where several attempts are made to start from the spark, excess gasoline often accumulates in the cylinders and cuts the oil off the pistons, due to the large clearances. This is apt to result in scored cylinders.

I think the principal objection to the Liberty ignition system is the location of the ignition heads. They were, of course, placed in their present position to obtain simplicity and light weight, but in some installations they are in the way of a permanent bulkhead, and would be better located if placed at the side. It would, of course, add something to the weight to place them anywhere else, and this is a factor which would have to be taken into consideration. Since the Liberty engine was designed, some very excellent twelve-cylinder magnetos have been developed, and it is entirely possible that in laying out a new design at the present time a magneto installation might be provided which would be just as light and just as reliable as the generator type used on the Liberty. This is a matter which would have to be proved by actual design and exhaustive experimental work.

Carburetion

At the time the Liberty engine was designed, the only proved-out aircraft carbureter available in this country was the old-style single-venturi Zenith, and, although we knew that this carbureter would not be entirely satisfactory, we had to specify it until such time as we could get definite information on something better.

Figs. 1, 4 and 5 show the arrangement of the Zenith carbureter, the intake header and water outlet arrangements. It will be noted that four intake headers are used, each serving three cylinders. It will also be noted that hot water is taken out of the top of the cylinders into water-jackets on top of the intake headers and piped from there to the radiator inlet. This arrangement of intake header proved very satisfactory, and resulted in very good distribution at all altitudes. It will be noted that the throttle-valves in the carbureter were arranged fore and aft, instead of crosswise, to prevent interfering with the distribution under throttled conditions. This arrangement proved very satisfactory. The altitude adjustment originally provided on these carbureters had very little effect on the mixture and was, therefore, unsatisfactory.

No strainers were provided in the original carbureter design, as it was thought that a strainer could be located in a more accessible place. Experience proved this idea to be wrong, as small particles from the rubber hose connections would work into the carbureter and block the jets. This was particularly annoying, as the carbureters are located in an inaccessible place, and it was a considerable job to remove the jets and clean them out.

It will be noted from the drawings that individual air scoops were fitted to each carbureter, and that no provision was made for carrying these intakes outside the bonnet. Although these scoops were drained overboard, the drain was effective only with the plane level or climbing, and a flooding carbureter on the glide would spill gasoline over the engine. If backfire occurred after this had happened, the plane might be set on fire. As soon as the engines were received overseas where they had had experience with fires, various modifications were promptly made to reduce the fire hazard, before the planes were flown, and we were requested to change the design as quickly as possible, to overcome this trouble.

While making a change to reduce the fire hazard, we decided to alter the altitude control also and provide

screens at the carbureter and beyond all hose connections. Figs. 9 and 10 show the revised construction, which it was intended should be in all production Jan. 1, 1919. The change in the altitude adjustment consisted simply in some rearrangement of the passages, and the construction, as finally worked out, was so simple as to make it possible to make this change in the field. To provide for a screen, a small aluminum casting *I*, Fig. 9, was provided, and arranged so that it would screw on the old carbureter. This casting was provided with a nipple to receive the gasoline hose connection, and the screen was easily removable by taking off the nut *J*.

To prevent the possibility of fire, the individual air intakes were removed from the carbureter, as well as their retaining springs, and a single long intake *A* was provided and held on by spring bails *C*. This intake was machined at its center to receive a large single intake pipe *B* extending up through the center of the engine and out through the bonnet. The top end of this pipe was cut off at an angle of 25 deg. A dowel *D* engaged a slot in the intake pipe *B* and prevented it from turning. A clamp band *E* and E_1 was arranged to anchor the intake pipe *B* to suitable cap screws already existing in the intake headers. The fragmentary plan view, Fig. 10, shows this rearrangement and the way it is necessary to bend the water outlet pipe to permit the installa-

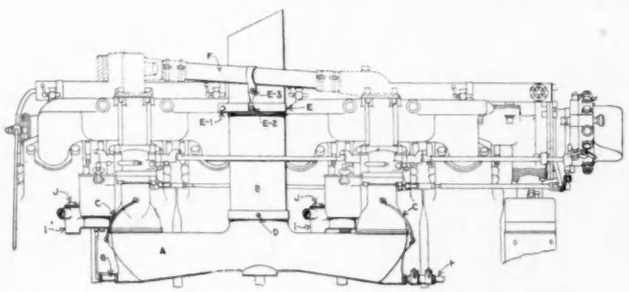


FIG. 9 — LONGITUDINAL ELEVATION SHOWING REVISED CARBURETER ARRANGEMENT

tion of the new intake pipe *B*. The intake header *A* is provided with nipples *G* at each end, so that overflow pipes can be attached and carried outside the fuselage. It is obvious that this provides for the complete draining away of all stray gasoline, whether the plane is climbing, diving or flying level. This new arrangement of altitude control, carbureter screen and intake pipe, has been extensively tested out in the air, and has proved to be exceedingly satisfactory.

The revised altitude control was worked out first and went into production in the early summer of 1918, and it is my understanding that all engines were equipped with this improved altitude control before being used at the front. Vague rumors to the effect that the Liberty engine has excessive gasoline consumption have been pretty generally circulated, and this, of course, if true, would be serious. It is obvious that all other things being equal, the gasoline consumption of the engine will be in proportion to the horsepower developed. All well-known aircraft engines at the present time have about the same gasoline consumption per horsepower-hour. This runs from 0.48 to 0.56 lb. per b.hp.-hr., depending on conditions. In this respect the Liberty engine is no better, and no worse, than other well-known designs.

Running wide-open near sea level, the Liberty engine will develop 400 to 420 hp. and granting that it develops the average, that is, 410 hp., and that the average ser-

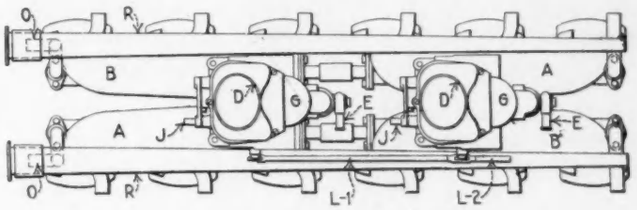


FIG. 10—PLAN VIEW OF REVISED INTAKE HEADER ARRANGEMENT

vice conditions maintain, it will probably have a gasoline consumption of 0.52 lb. per b.hp.-hr. Under these conditions it would burn 213.2 lb., or approximately 35½ gal. per hr. The same engine flying wide-open at 15,000 ft. would be developing approximately 295 hp. and if the altitude adjustment was properly used, the gasoline consumption would be reduced in approximately the same ratio. This would bring the consumption down to 153 lb., or roughly 25½ gal. per hr. As a matter of fact, however, the general practice is to throttle down, except for short periods of time when it is desired to obtain maximum speed. Where a plane is capable of making 120 miles per hr. at 15,000 ft. altitude, it is good practice to throttle down to between 90 and 100 miles, thus enormously reducing the horsepower and gasoline consumption per hour, without seriously affecting the distance traveled. We know from practice that with a Liberty-Twelve mounted in a DeHaviland Four or Nine plane, we can average about 100 miles per hr. in cross-country flying at 15,000 ft. on 20 to 22 gal. of gasoline per hr. Throttling down still more will further reduce the gasoline consumption, and it is possible to fly a DeHaviland Liberty-equipped plane at about 75 miles per hr. on 17 gal. of gasoline per hr.

Figs. 7 and 8 give absolutely accurate data as to gasoline and oil consumption of Liberty engines running wide open at 1600 r.p.m. near sea level.

A rather radical carbureter design, which was worked out for the Liberty-Twelve, while only used experimentally, gave some very promising results. Fig. 11 shows this experimental carbureter and intake header arrangement, and Fig. 12 is a fragmentary plan view showing the same arrangement. Fig. 13 is a diagramatic sectional drawing, showing the principal parts of the experimental carbureter. It will be noted that two carbureters are shown, as in the standard Liberty, but they are what might be called a inverted type. Without going into detail as to the construction of this carbureter, it will be noted that the double-venturi arrangement, which has been highly developed during the war, makes this construction possible. The reason for this is clearly shown in Fig. 13. It will be noted that this type of carbureter cannot flood into the engine, as would be the case in the ordinary type of carbureter turned upside-down. In Fig. 13, *D* is the needle-valve float, *Y* the drain compartment

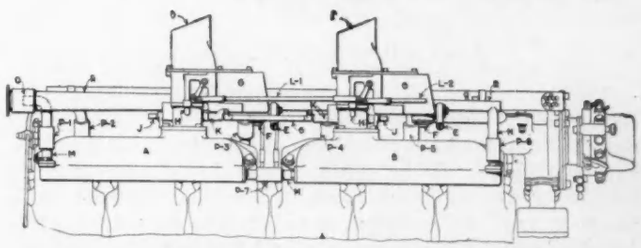


FIG. 11—LONGITUDINAL ELEVATION SHOWING EXPERIMENTAL CARBURETER AND INTAKE HEADER ARRANGEMENT

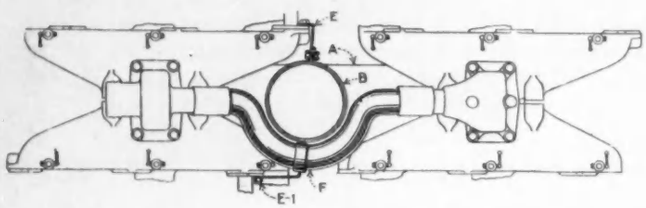


FIG. 12—FRAGMENTARY PLAN VIEW SHOWING EXPERIMENTAL CARBURETER AND INTAKE HEADER ARRANGEMENT

connected to an overflow pipe, *K* the altitude valve, *F* the jet, *N* the compensator well, *M* the compensator feed holes, *I* the compensator, *L* the idling mixture passage, *O* the passage to the secondary choke, and *P* the secondary choke. This arrangement is very desirable for airplane use, as it provides short separate intakes from each carbureter that project directly out through the bonnet and make fire from backfire impossible. Another important advantage of this arrangement is the matter of accessibility, as the carbureters are right up on top of the engine where all connections and adjustments can easily be got at, and it leaves the V between the cylinders absolutely clear for machine-gun installation.

It is obvious that this type of carbureter requires a different kind of intake header, and as designed for the experimental job there were rights and lefts, as shown by *A* and *B*. This construction made it necessary to change the water outlet headers, and provide a separate outlet manifold *R* for each line of cylinders. On account of the gas impinging against the bottom of the header in this construction, it is necessary to place the water-jackets on the bottom of the intake headers, and to get hot water into these jackets, a connection was made at the rear end through the water outlet manifold *R* by the pipe *N* and hose *P*-6. The jackets were connected at the center by the nipples *M* and hose *P*-7. At the front end the jackets were connected to the water manifold *R*, by the nipple *M*, hose *P*-1 and pipe *O*. This pipe *O* was arranged to extend inside and then turn forward with the flow to form an ejector and thereby induce some of the hot water to flow through the jackets. This construction worked out very satisfactorily and the intake header seemed to keep just as hot as in the standard Liberty construction.

As stated above, this whole inverted carbureter arrangement was treated as a purely experimental proposition, as it was recognized that it would be impossible to put it into production, owing to the fact that absolutely new carbureters would require new tooling-up, as well as many other small parts. I believe, however, that all those who have tested this arrangement believe it to be the best possible installation for the Liberty engine. This carbureter arrangement has every advantage of all such arrangements that I know of combined, with one exception; it does not provide for gravity feed.

ANGLE BETWEEN CYLINDERS

The Liberty engine has been criticised on account of its cylinders having been set in an inclined angle of 45 deg. All experts in engine design know that a six-cylinder engine is perfectly balanced. Two six-cylinder engines hooked to the same crankshaft are also perfectly balanced at any angle, except as to impulse frequency. Before designing the Liberty engine I had experimented extensively with various angles of cylinders, and knew that the 45-deg. arrangement would not be noticeable, so far as lack of smooth running was concerned, and that it had distinct advantage, not only in that it reduced head resistance, but also that it reduced synchronous vibration of the crankshaft, due to the breaking up of the evenly spaced impulses.

The cover over the oil-pump in the Liberty engine is held on by a spring bail which, while readily detachable, cannot jar loose and come off. This is a well-known mechanical device which has been used for years for exactly similar purposes. This little device, however, has been the subject of widely circulated criticism, and I do not know how much it has cost the Government to investigate persistent criticisms on this device sent in by irresponsible people.

WEIGHT PER HORSEPOWER

I believe it is pretty generally known that the Liberty engine weighs approximately 2 lb. per hp. By using still better materials, making the engine considerably harder to manufacture and lowering the factor of safety, which is pretty high, it would be possible to bring the weight down to about 1.8 lb. per hp. This would greatly increase production troubles, would require more skilled mechanics to keep it in working order, and would, therefore, in my opinion, be an inadvisable move.

I believe that one of the outstanding features of the Liberty engine, as it is now being manufactured, is its reliability. I have flown the Liberty engine thousands of miles cross-country and have yet to make a forced landing. This reliability has, of course, been developed by extensive experimental work in the air and close attention to details of manufacture and inspection.

Reports have been promiscuously circulated that while the Liberty engine has proved to be good for large bombing machines, it cannot be used in a small fast fighting or chasse machine. It was never intended that the Liberty-Twelve should be put in a small single-seater

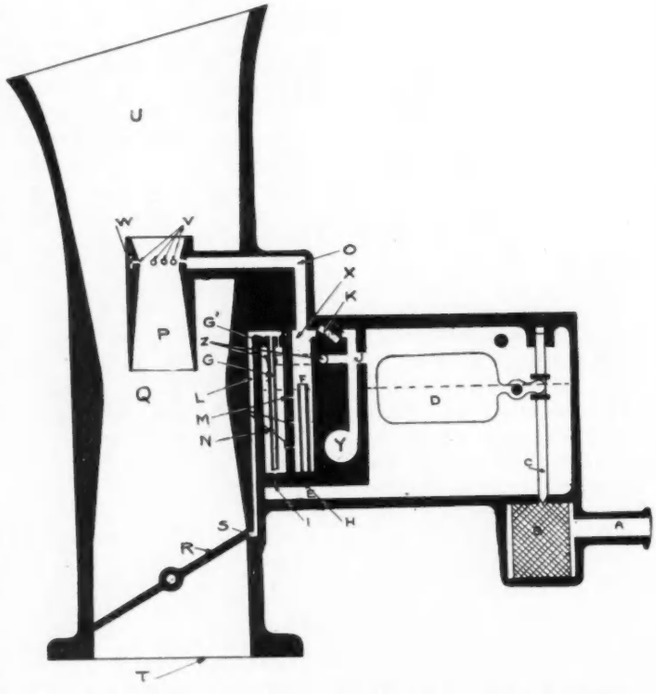


FIG. 13—DIAGRAMMATIC SECTIONAL ELEVATION OF EXPERIMENTAL CARBURETER

chasse machine, and that is the reason the Liberty-Eight was developed. It was our original plan to put the Liberty-Eight into production and use it for just such small machines, but when our program was finally made up, based on advice from abroad, it did not include a single-seated chasse machine, and for that reason, the eight-cylinder was not put into production at the time. Some four or five months ago it was decided that we should develop a single-seater chasse machine in this country, and the Liberty-Eight was promptly brought out and ordered into production. Airplane designers generally agreed that the Liberty eight-cylinder engine, developing 300 hp. and weighing approximately 600 lb., will make a very satisfactory powerplant for a plane of this type.

Air Performance

Owing to the fact that the performance of an airplane must be measured in the air, it is a rather involved matter to make a full-flight test requiring, as it does, a number of special instruments, a well-qualified pilot and proper technical experts to make the necessary corrections for temperature, air density, etc., after the readings have been secured. When we first started making full-flight tests in this country, we did not have the proper equipment, and a number of tests were made and reported, which were not on a comparative basis with similar tests of allied planes made in Europe. Quite naturally this has led to a misunderstanding, and it has been claimed that the DeHaviland-Four plane equipped with the Liberty engine, is not as good as Allied planes equipped with engines of much less horsepower.

To throw some light on this subject, I am giving below a few comparative figures covering foreign planes. They give average performance of three well-known planes, namely, the French Salmsom 270 hp., English DH-4, using the Siddeley 240-hp. engine, and the Italian Pomilio E, using the Fiat 240 hp. The USDH-4 is, of course, equipped with the Liberty-Twelve. The figures on allied planes were secured from official technical reports from abroad and figures on the USDH-4 were taken from tests made by the Technical Section of the Department of Military Aeronautics and the Engineering Division of the Bureau of Aircraft Production.

OBSERVATION PLANE

	Average Foreign	DH-4
Power, hp.	266.6	400
Speed at sea level, miles per hr.	116.8	128
Climb to 10,000 ft.	9¼ min.	7½ min.
Ceiling, ft.	20,267	21,000
Endurance (cruising)	3½ hr.	4⅓ hr.

DAY BOMBER

Power, hp.	266.6	400
Speed at sea level, miles per hr.	110.5	118
Climb to 10,000 ft.	11¼ min.	11 min.
Ceiling, ft.	16,000	17,500
Endurance (cruising)	3½ hr.	4 hr.
Bomb load	423 lb.	223 lb.

RADIUS OF ACTION, MILES

British DH-9	256
British DH-4	244
Breguet	151
USDH-4	310

In the above comparison it will be noted that the USDH-4 equipped with the Liberty-Twelve shows up well in all cases, except that of the load of bombs carried on a day bomber. This machine was originally designed for a 240-hp. engine and when equipped with a slightly heavier 400-hp. Liberty, plus the necessary gasoline for a larger engine, its carrying capacity is naturally cut down. It was to take care of this work that the USD-9-A was being put into production just as the armistice was signed. This machine has 500 sq. ft. of surface and carries 500 lb. of bombs with practically the same performance as the USDH-4. In addition to the USD-9-A, the following planes were being put into production at the time the armistice was signed:

VE-7 advanced training machine, equipped with 150 hp. Hispano-Suiza

Le Pere two-seater fighting machine, equipped with the Liberty-Twelve

Glenn Martin day or night bombing machine, equipped with two Liberty-Twelves

U. S. Bristol fighting machine, equipped with the Liberty-Eight

Many other new types of planes were in the experimental state, including several designs of single-seater fighting machines around the 300-hp. Hispano and Liberty-Eight.

The Discussion

F. H. Trego:—The production of our plant was finally transferred to the Ordnance Department. Engines to be used in the large tanks called for in the Allied tank program required some few changes in the design, such as the incorporation of a flywheel and the welding in of a tie between the intake and exhaust elbows to prevent the cracking of the jacket at the top, and this we do in regular production. In connection with the testing of the engines for tank service, the United States Ordnance Department endeavored to comply with the testing specifications as suggested by the British Tank Service, and one of these tests called for four runs of 50 hr. each with wide-open throttle, on dynamometer, at 1400 r.p.m., all parts of the engine being carefully measured before and after each test. Outside of the cracking of the jackets, which was later corrected by the welding in of a tie, we found a tendency of the babbitt to break away from the bronze backing in the connecting-rod bearings in a spot about as large as a ten-cent piece, directly opposite the oil-hole in the crankshaft at the instant of the explosion of the cylinder carrying the plain end rod. The hole in the crankshaft at this point has a depression on each side of it, leaving the babbitt unsupported for a considerable area and owing to the fact that the plain-end rod which runs on the back of the bronze bushing has 0.005 to 0.0065 in. clearance we decided that a rapping action was set up by this rod on the outside of the bronze and that this continual rapping directly behind the unsupported portion of the babbitt had a tendency to break it away from the bronze. To eliminate this difficulty we had a shaft made up with an oil-hole drilled at a point 30 deg. in advance of the top dead center when the plain-end rod piston is at the outer end of its stroke. Thus a flow of oil on the center line portion of the bearing was assured before the explosion took place. This also provided complete support for the babbitt under the plain-end rod at the instant of the explosion. Tests of this shaft seemed to prove our theory, and we now consider it good practice, even with the single rod, as it assures an uninterrupted bearing surface under the rod at the instant of explosion. We also omitted the depressions on each side of the drilled hole and simply broke the sharp edge of the hole. After a test of 46 hr. under full load at 1400 r.p.m. the bearings were found to be in excellent condition.

T. S. Kemble:—The Liberty aircraft engine stands as a monument to the daring, courage and cooperation of the engineers, manufacturers and all who had a part in

the program. The first engines were completed in phenomenally short time. Production, already gratifying, was growing rapidly when the armistice was signed. Delays caused by necessary alterations in design occasioned no surprise to those in private enterprise who were already familiar with the difficulties involved.

With the war apparently ended, the necessity for tremendous production in aeronautics has ceased, Government orders have been cancelled wholesale and the entire industry pauses to catch its breath, consolidate its organizations and alter its course to meet the new conditions. Only short-sighted blundering on the part of the industry and of the Government could cloud even the immediate future under these new conditions, for the probabreast of the times. Even before the armistice, privately developed planes had shown performance far in advance of those possessed by any of the Allied forces, and these are only a foretaste of what is to come.

Let us as Americans and engineers give serious consideration to the fact that, if another unfortunate war should arise, the initial and perhaps the final advantage in that conflict will lie with the nation which has attained the highest development in aeronautics. Our country, with its broad areas and its vast industrial development, can obtain the lead more easily than any other.

H. E. MORTON:—It is nearly always true that the user must decide the requirements, and, as the Government is the customer, so far as military aircraft equipment is

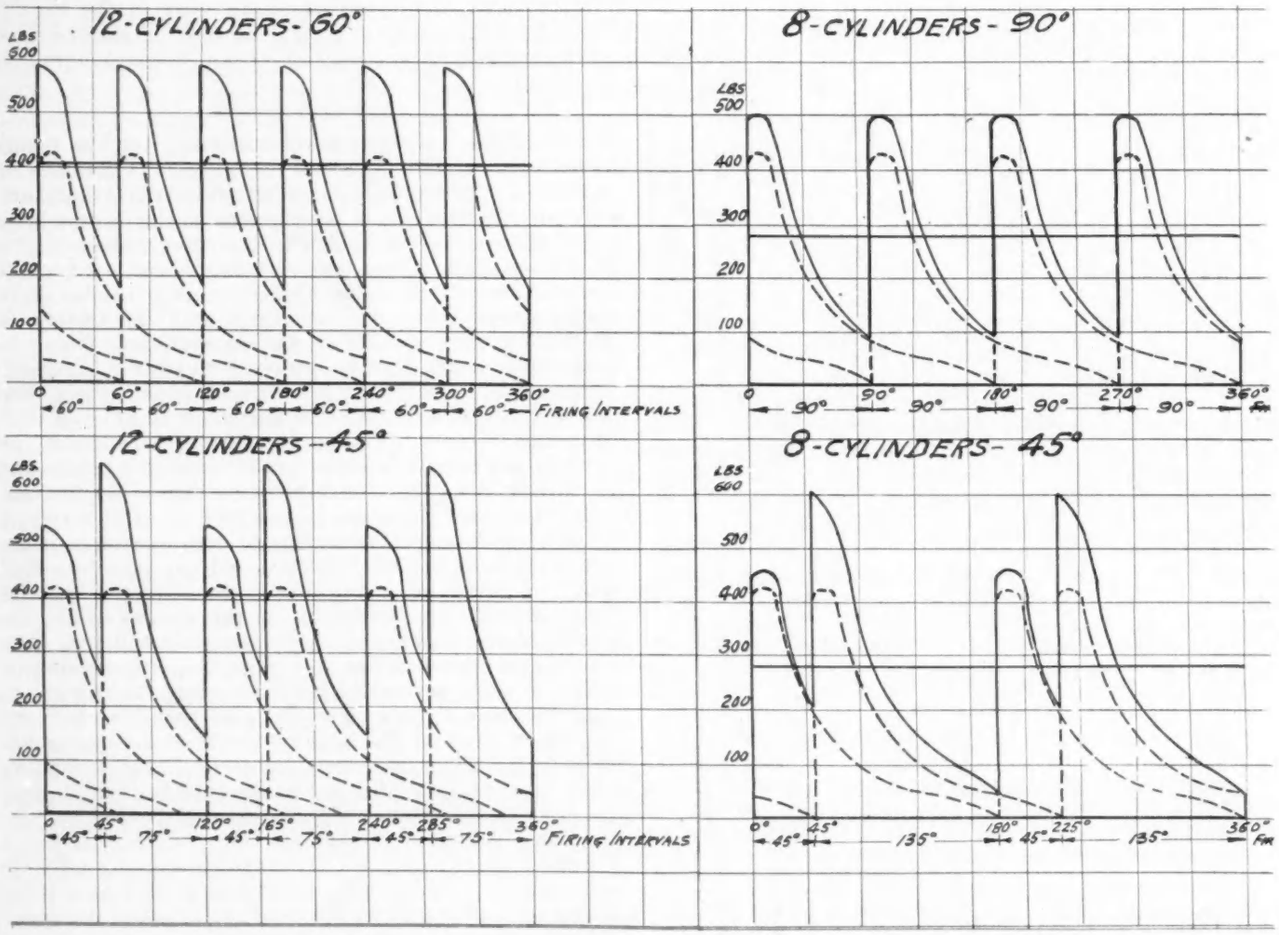


DIAGRAM SHOWING THE OVERLAPPING OF POWER IMPULSES AND IRREGULARITY OF FIRING THE EIGHT AND TWELVE CYLINDER LIBERTY ENGINES

lem of adapting recent progress to commercial purposes is remarkably simple, and we have enough men of clear vision to make the application rapid. The present knowledge of the art, together with the foresight and courage of engineers and business men, assure immediate prosecution of commercial development, which, beginning somewhat slowly, will gather momentum rapidly.

Many of us believe that our military authorities now realize thoroughly how exceedingly temporary is the standardization of aeronautic engines and planes and that they will give substantial encouragement to development by private enterprise of those vast improvements over all their present types which are necessary to keep

concerned, I maintain that the only reason we were unprepared or behind the world in airplane engine design, was the fact that we were working to specifications which were suited possibly for commercial aircraft, but not for military machinery. The Packard engine, together with practically all the other American engines available in early 1917, were in what is now the heavier class. Of course, the technical section of the Department of Military Aeronautics now has complete data on military aircraft requirements. If this section will keep such data up to the minute and in such shape that they can be studied at any time by accredited engineers in the industry I know the engineers will gladly cooperate.

The phenomenal development of the Liberty engine was made possible only through the possession by its designers of the latest information on requirements. Similarly when, at a meeting in Washington of the Manufacturers' Aircraft Association with the United States and foreign representatives, it was stated the engines must not weigh over 2½ lb. per hp., and tests would be modified accordingly, work was immediately started on such engines. This meeting took place in May, 1917, and in just 10 weeks the Sturtevant 210-hp. engine, weighing 500 lb., or 2.38 lb. per hp., was flying daily. This is merely cited as another illustration of what can be done when the requirements and limitations are known.

Although there are double breakers, coils and distributors, is the ignition a double system since it depends on one generator for energy, while running, and one battery when starting? It would seem as though this was putting a great deal of responsibility on the storage battery in case of a stalled engine away from a supply base.

CHARLES B. KING:—This country was building two types of aircraft engines which were used at the front prior to the development of the Liberty engine. These engines were the Gnome and the Hispano-Suiza. The French Section Technique Report No. 98, November, 1917, was issued about 6 months after the start was made on the Liberty engine and gives the weight of the Lorraine Dietrich engine bare as 606 lb., an increase of 78 lb. over the figures given Col. Vincent; also the weight of the engine complete with radiator and water was given as 769 lb., or an increase of 98 lb. This increase may have been due to later structural changes. This engine was of the eight-cylinder type with cylinders set at 90 deg. A few of these engines were built and put into service late in 1917.

A few days after the design work had started at Washington, at a late supper at the New Willard Hotel, I suggested to those present that the name Liberty engine be adopted. This suggestion was very well received and the next day I passed the title along, and in each instance it was endorsed and seemed to be adopted almost at once. It is quite possible that Admiral Taylor may have made the title official at one of the Aircraft Board meetings. Col. Vincent at this time was in the employ of the Packard company and later came to me saying that he did not want to do anything about the name until he had taken it up with his directors.

I agree with Col. Vincent that anything under 2 lb. per hp. is not desirable, my firm belief being that something over that figure stands for less vibration and longer life. It takes a certain mass to absorb the explosive effect, and the commercial engine of tomorrow will be of considerably more weight per horsepower.

The Liberty Eight will be a less successful engine than the Twelve, owing to the 45-deg. angle between cylinders. The lapping of power impulses and the irregularity of firing are apparent from a study of the accompanying diagram, the firing order being 45-135-45-135. The vibration of this engine in a plane will be quite marked.

ROAD BUILDING IN 1919

THE enlarged road construction program recently authorized by Congress indicates that a greater volume of highway construction will be accomplished in 1919 than in any previous year. According to a statement issued by the Department of Agriculture, the amount of Federal funds available for road building on March 1 was over $72,900,000, and under the provisions of the Federal Aid Road Act a like sum must be raised by the states, making a total of $145,800,000, including approximately $9,800,000 from Federal and State sources for roads in the National Forests. On July 1, $95,000,000 more will be available for general road purposes and $4,000,000 for National Forest roads. This with equal contributions from the states will provide an additional $198,000,000 for Federal aid road work, making the aggregate amount available for the calendar year $343,800,000. This program, which is greater than any previous annual road building accomplishments in the country, will be supplemented by a large amount of work that will be carried on by the states and their various subdivisions without Federal aid. While the extent to which this will be done is uncertain, depending upon local labor, industrial and agricultural conditions, the present indications are that approximately $280,000,000 will be spent in this way.

There are only three limitations placed on the type of road to be constructed under the Federal Aid Road Act. These are that the roads shall be substantial in character, the cost of construction shall not exceed $20,000 per mile and the highway must be a public road, a major portion of which is now used, or can be used, or forms a connecting link not to exceed 10 miles in length of any road or roads now or hereafter used for the transportation of the United States mails. It is the plan of the Department of Agriculture to maintain the closest possible touch with the state highway department which will supervise the work, and it is contemplated that the American Association of State Highway Officials will designate some of its members to serve on an advisory committee to cooperate with the department in the administration and execution of the provisions of the Federal Aid Road Act.

Forty-four states have established definite systems of main highways, either by legislative action or by action of state and local officials, aggregating, according to the latest statistics, 203,523 miles, exclusive of a considerable mileage of local roads on which the states are granting aid. With additions, which are being made from time to time to these systems, and taking into account the four additional states on an average basis, it is expected that at least 250,000 miles of state highways, or 10 per cent of the total mileage, will receive attention this year.

Governors for Motor Trucks

By F. H. Critchfield (*Non-Member*)[1]

Minneapolis Section Paper

IN the works of one of the lesser read writers of the time of King George I of England, we find a reference to the "men of intemperate speed," who, regardless of life, limb or decorum, drove with careless abandon through the streets of London. Perhaps the writer was deploring the fact that a speed-limiting device had not yet been invented to curb the speed mania of the Jehu of his day, but he had the correct idea, although we may wonder just how such a contrivance would have been applicable on the horse-drawn vehicle of that period. In our own day we find it necessary not only to protect the public from the reckless driver, but to protect the truck and engine from themselves as well. This became apparent in the early day of the gas-engine-propelled vehicle. It was soon realized that there were potentials of destruction in the commercial engines, which, if left to the judgment of the average operator to guard against, would on account of their various diverging views of the mechanical fitness of things, prove the undoing of the most perfectly designed and sturdily constructed engine.

It was recognized, however, that any device of a remedial nature must be reciprocative or rather compensative in action, since the mere limiting of the speed without assuring the full power of which the engine is capable would necessarily decrease the value of the advantage gained from a longevity standpoint, and make necessary a much larger powerplant than would be actually required if the maximum power of a smaller unit were available at the safety speed. The same problem had been encountered in steam practice, and the means of solving it was a device consisting of two or three flyballs or weights revolving around a common axis. The force generated by this centrifugal action actuated a rod or lever usually connected directly to a valve, the opening or closing of which governed the amount of working fluid available for the operation of the powerplant. The fact that the functions of such a device must indeed be of a versatile nature to regulate the speed properly, while keeping the maximum power available as the occasion demanded, was responsible for the name "governor" being applied to it, and, considering its functions and their importance together with the consistency necessary for the effective maintenance of satisfactory powerplant operation, perhaps no happier word could have been chosen or one which would so adequately cover the entire range of its capabilities.

The benefit to be derived from an efficient governor cannot be overestimated. It is nature's law that no work of man is permanent or indestructible. This incontrovertible fact is responsible for all human endeavor and a large amount of human grief, and it is only logical therefore to attach no little importance to the temporary preservation, at least, of the work of our hands. Even with the knowledge gained by years of endeavor, science and costly experience, the maintenance of past standards of quality and workmanship is a battle royal, whether it be corkscrews or motor trucks.

[1]Engineer, Pierce Governor Co., Anderson, Ind.

Speed Regulation Necessary

A motor truck to meet the demands of the day must insure a maximum of service with a minimum of mechanical trouble, and no factor plays such an important part as an agent of destruction as excessive speed; the toll is paid in human lives and equipment wrecked or worn out before its alloted time, to say nothing of the detrimental effect on the highways. Whether it is because we are the greatest nation of hustlers on the globe which causes the American to plunge along at breakneck and nerve-racking speed, I am unable to say, but from my observation of the manner of mechanical operation in foreign lands, such as France, England, Germany and Italy, there is more need for speed-regulating devices in America than in any of the countries mentioned. There are fundamental laws which govern the design of the component units of commercial vehicles. We recognize the fact that there are limits to the weight necessary or allowable in the design of engines and motor trucks, and these limits must be maintained at least at the point where we can be assured of the correct relationship between the various parts which go to make up the complete assembly. It may be possible to design and construct a motor truck which from the standpoint of non-breakage would last as long as the owner might think a reasonable assumption of life, but such a vehicle would have points of vulnerability which no amount of surplus weight and strength would render immune from harm. The life of the engine bearings depends more upon the wear-resisting qualities of the material of which they are made than upon their weight. The recognition of this and other important truths of a like nature makes for the improvement of motor trucks from year to year on a basis of material quality rather than weight, but it would be temerity indeed for a manufacturer to assume that because of the quality of material, excellence of design and accuracy of mechanical work he had solved even to a limited degree the problem of all ages, construction permanency. This is the underlying reason for the universal demand for and use of governors.

Various estimates have been made from time to time as to the life of a motor truck and there are a number of opinions on the subject. It is my judgment that the average motor truck is capable of about 4 or 5 yr. of maximum service, governed largely by the quality of manufacture and the care expended in its upkeep. In making this statement, the stand is taken that the life of a truck for purposes of statistics is considered at an end when the upkeep with regard to service and general maintenance as distinguished from expense incidental to accident, etc., is equal to approximately 50 per cent of the value of the truck, this value taking into account all factors of depreciation. Individual trucks have outlived this period of longevity, but it will be evidenced that the average trucks are able to reach this period of service only by the use of such safety devices and standards of disciplinary care as will insure the maximum service with a minimum of expense. It is not to be doubted that from

a standpoint of economy a governor is an absolute essential, whether considered in relation to fuel, tires or general efficiency. Most of the fuel waste is occasioned by excess speed and unnecessarily drastic acceleration, as it has been demonstrated time and time again that the most efficient operation of a truck is obtained at a road speed of from 10 to 20 miles per hr., depending upon the size of the vehicle and the engine speed necessary to obtain this road speed. Experience has shown that a violation of these speed limits is almost certain to be a forerunner of disaster. It is useless to contend, as some manufacturers have, that the question of speed is largely a matter to be left to the judgment of the operator. In contradiction of this theory, it may be said that 75 per cent of motorists violate the community speed regulations in that the strict limits of permissible speed are not observed, and it is hardly to be expected that the servant will observe the rules where the master fails. If the average motor truck drivers had the intelligence with which some of the manufacturers credit them, they would have more desirable positions than their present occupations.

Flyball Governors Most Extensively Used

The desirability of governors must have become evident almost at the birth of the motor-truck industry, for in the earliest designs of these vehicles we find provision made for the inclusion of these instruments. They were usually of the truck builder's own design and construction, as this period was before the day of the large accessory manufacturers as is now the rule, and it is worthy of note that the type of governor adopted by the majority of truck builders was of the flyball or centrifugal principle long used on steam engines of all kinds and known as the Watt, Porter, Proll, Hartnell, Pickering, Head and Farcot governors. These instruments varied somewhat in design and method of application, but in principle they were identical. The two or three balls or weights when rotated by some agency of the engine itself would fly away from or toward their axis of revolution according as their speed was increased or diminished. By suitable linkwork or other connections this motion was used to actuate a throttle-valve in the venturi through which the working fluid must pass into the combustion chamber, and it is upon this principle that all governors of the flyball type operate today. Statistics show that more than 86 per cent of the motor truck builders equip their product with the centrifugal governor. As the driving power necessary to produce the centrifugal force of the governor is derived from the engine itself, the governor becomes an integral part of the engine, is responsive to all of its manifestations and, being automatically reciprocative in principle, is able to compensate for any stress, strain or unusual demand on the engine and maintain a consistent supply of power. The throttle of this governor being of the same general shape and dimension as the carbureter throttle, offers no obstruction to the flow of fuel, avoids condensation and is consequently not subject to climatic conditions. The full power of the engine itself is always available and it is not necessary to make any changes in carbureter adjustment to obtain satisfactory performance.

Of all accessories common to the commercial vehicle, none is so little understood or subjected to so much abuse or rather systematic neglect as the governor. A speed-limiting device does not meet with the approval of the average driver, and it is just this spirit of enmity that is proving the wisdom of its use; testimonials to the economy and effectiveness of motor trucks equipped with governors over those which are left to the mercy of the driver can be obtained in large number. Most of the governors which do not give satisfaction have been subjected to tampering or have not had even the ordinary lubrication which common sense would dictate. Every effort is made to build the present-day governors as fool-proof as possible, but since the discipline exercised over the average driver is lax in the extreme, no method occurs to me of preventing the operator from indulging his small-boy penchant for tampering, other than to lock the entire truck in a safety vault, leaving the driver outside.

The life of a governor when free from these conditions can reasonably be assumed to be of the same duration as the truck itself. It matters little what class of service the trucks are engaged in as far as any effect on the governor is concerned, since they are constructed of good material and of as heavy structure as the room allotted to them will permit, and their performance and upkeep need give no concern if free from the dangers of meddling and non-lubrication. Engine builders have realized the conservation possibilities of governors and with few exceptions have provided suitable drives and connections and recommended that governors be used in connection with their product.

In general, it may be said without fear of successful contradiction that the use of a governor is indispensable. Regardless of the quality or price of a truck, there is no accessory of equal value to the owner, builder or parts manufacturer. With such a speed-limiting device installed on his truck the owner can feel that once adjusted to the proper speed and with ordinary attention paid to lubrication, his truck will be operating at a sensible and efficient speed, the law of the land will be observed and the chances of having damage suits to fight considerably minimized. In addition his truck will be longer lived, its upkeep will be reduced to an appreciable extent and the resale value will be much higher than if he had left it to the whim of his driver to determine at what speed it should operate.

To the truck and engine builder nothing else offers such protection to the reputation of his product. He has learned from experience that 75 per cent of all troubles incident to the operation of trucks and engines is due to the general tendency to overspeed and that no mechanical or material excellence will neutralize this dangerous pastime or its effects. As every reputable manufacturer builds his product in the hope that its service and dependability will bring in repeat orders, he will naturally feel that any method of assuring a continuance of service and consistency is well worth the small premium of such insurance.

AUTOMOBILE LOCKING DEVICES

A meeting of the S. A. E. Committee on Automobile Locking Devices was held at Detroit on April 24 in the rooms of the Detroit Section of the Society. Representatives of the National Automobile Chamber of Commerce and of the Underwriters' Laboratories attended the meeting. William MacGlashan is chairman of the S. A. E. committee.

Vol. IV May, 1919 No. 5

Tanks

By HERBERT W. ALDEN, U. S. A.[1] (*Member*)

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

THE purpose of this paper is not a technical consideration of the subject of tanks. The subject is too young and in too rapid a state of flux to warrant such treatment. From time to time, since the signing of the armistice, much technical data have been published, and more will be. Duplication of these here would be a waste of time. Therefore, this paper will be devoted to those phases of the subject which might not otherwise be published.

Like many another trite saying, the old adage that "there is nothing new under the sun" is only partly true. When some old idea or device is modified and developed to a point where distinctly new results are accomplished, then that thing is, by right, entitled to be called new. The recent war is responsible for many such new forms of old ideas, and not the least by any means among these things is the tank, which has played so important a part in winning the war.

REASONS FOR DEVELOPMENT OF THE TANK

The origin of the name has been the cause of many fancy stories. The reason for choosing this name, however, was simply as a blind to conceal the real purpose. There is always a cause for every result, and there was a very serious cause for the coming of the tank. It did not "just happen." Nothing ever does, for that matter. The very urgent need which brought the tank into existence was the menace of the machine gun. The tank problem cannot be correctly understood nor solved if this fact is lost sight of. This is the first war in which the machine gun was used in large numbers. It was known before, and used to some extent, but its use in a wholesale manner never before occurred. This use in large numbers very nearly revolutionized warfare. Enough machine guns, properly placed, were almost impregnable. Behind barbed wire, and in concrete redoubts, they could be taken only at a great sacrifice of man power—usually too great to be considered.

Something had to be done. The first method was that of intensive preliminary bombardment; that is, firing a stupendous quantity of shells into a given area. The prodigal use of shells for this purpose was staggering, running literally into the millions. Even this amazing use of ammunition, however, would have been warranted if consistent results had been secured. But they were not.

In the first place, the machine guns were not completely obliterated, strange as this may seem. One notable example was the so-called Pomern Redoubt in the Ypres sector, which I examined in the fall of 1917. It is not far from Paeschaendale Ridge, and the fighting at this place was in full sight at the time. This emplacement was in reality a series of continuous "pill boxes" of reinforced concrete, laid out in an arc of about 45 deg., the chord of the arc being about 700 ft., and including perhaps fifty machine guns. It faced the British on a gentle slope, and the roof of the emplacement was perhaps 3 to 4 ft. above the ground. The ground all about had been completely pulverized by shell fire. Many shots had struck the redoubt, but it was still intact and serviceable. Repeated infantry assaults were made, but to no purpose. Tanks were then brought up, and two hours was all the time they needed. Being immune against machine-gun fire, they waddled right up to and over the emplacement and took it from the rear.

In the second place, the pulverizing of the ground made it almost impassable for infantry, and reduced the effectiveness of infantry assault. The difficulty of marching across this kind of ground cannot be described. It has to be done in person to be appreciated. Many hours of walking over such places has given me an increased respect for the endurance of the modern soldier. That he can advance miles through this terrain and then be ready to fight as he does is almost unbelievable.

In the third place, preliminary bombardment completely eliminates the element of surprise. It is like pausing in a prize fight and telling one's opponent that the next blow is coming on the point of his jaw, so he had best get his guard up.

It is quite plain from the above that something new had to come, and come it did in the form of the tank. Fundamentally, the tank is simply a device that can come to close quarters with a machine gun and destroy it or its crew. The armored motor car had been used to some extent prior to this war. It was confined, however, to fairly good terrain. Also, to armor it sufficiently to keep out armor-piercing bullets rendered it too clumsy. Increasing its size helped little, for it was still on wheels, and no wheeled vehicle would answer. The track-laying type of vehicle was, of course, old, but nothing had ever been constructed capable of negotiating the terrain of a modern battlefield.

The tank was the successful solution of this many-sided problem. It should be remembered that the tank is fundamentally a man killer and not a fort destroyer; also that its greatest defense against heavy artillery fire lies not in the armor it carries but in its own speed and mobility. This will be referred to more in detail later.

The number of fantastic ideas of supertanks sufficiently heavily armored to withstand artillery fire has been legion. Those who have been engaged in the solution of the tank problem have been bombarded from above and below, from within and without, by the inventors of ponderous machines whose very "ponderosity" would be their own undoing. On this subject I speak feelingly, as I have been the target of a steady fire of criticism from those who did not understand the real issues.

It may seem that this matter has been dealt with too much in detail, but it is my desire to get the real problem before you, as it is all too little understood. This was true even of the military authorities themselves in the early days, and the general public may be excused if it also is a little at sea.

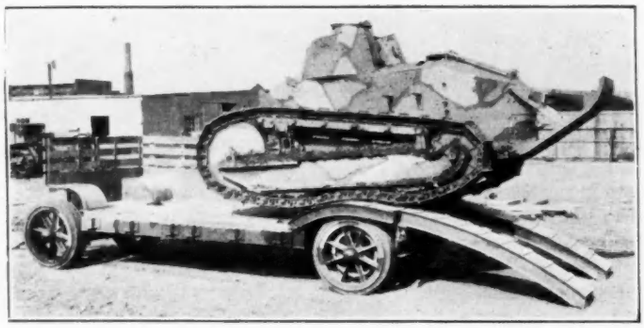
It is doubtful if any new means of warfare has had so hard a time getting started and securing its just consideration as has the tank. Thanks, however, to its inherent value, it has steadily advanced and demon-

[1]Formerly assistant to Chief of Ordnance in charge of tank engineering work and now vice-president, Timken-Detroit Axle Co., Detroit, Mich.

strated its worth, and now is universally accepted as an indispensable arm of the service. Its future is secure. Its development has only just begun, and even those who have given it their individual attention feel that it is yet in its infancy and is capable of wonderful improvement.

Work Done by the English

To the English belongs the credit of producing the first practical fighting machine of this type. Their first attempt was along the lines of a heavy armored car. This



A 6-Ton Tank Being Loaded on a Trailer

was not successful. Then they turned to the track-laying type of vehicle. It should be said here that the first man, probably, who suggested the idea of a large fighting vehicle, and who had a sufficiently clear grasp of the problem, was Lieut.-Col., now Brig.-Gen., Swinton, who had, several years before the war, broached the idea, and early in the war had argued its value and the tactics accompanying its use.

It remained for two others to make it mechanically practicable. Major Wilson of the British Army and Sir William Tritton, manufacturer of agricultural machinery, worked on the problem of the track-laying type, using the American type of track as a foundation. It seems to me that the really new feature of the large type of tank was carrying the track all the way around the body of the machine, and this design was the result of the joint labor of these two men. To negotiate wide trenches required a long machine. To climb over obstructions, particularly vertical walls, required great climbing ability at the front end. These requirements were both met in the long, rigid type of vehicle and the all-around track working up on a sloping front. These features, which were first combined by the two men mentioned, marked the design of a new type of machine, which was a practical success from the start.

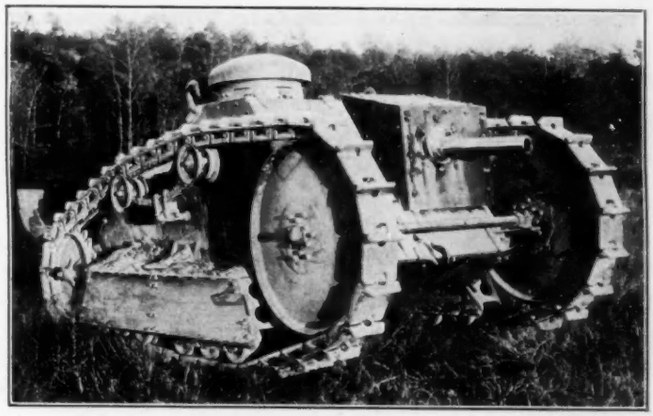
We have now seen how the main idea was conceived, almost in its entirety, by Swinton, and how this idea was made mechanically possible by Wilson and Tritton. Many an excellent thing, however, dies right at this stage for want of some one with faith in its usefulness and persistence in its creation to "put it over," as we say. This part of the task fell to two other officers, Sir E. d'Eyncourt and Lieut.-Col. Sir A. G. Stern. Too much credit cannot be given to them, for in the early days ninety-nine out of every hundred men looked upon the scheme as chimerical. They were unable to get much backing, but their faith and persistence finally were successful.

They were handicapped by the critical situation of English production resources at the time, and were allowed to use only such material as could be made available. Hence they had to use a heavy, stationary type of engine. A 100-hp. unit was the largest available. It was inadequate to give the best results, and many of the early difficulties of operation are traceable to lack of power. Some of the essentials of tank design were, naturally, not appreciated at first. Besides a lack of power, these earlier machines suffered from too great a unit ground pressure. This caused them often to get mired in soft mud.

The Tanks in Action

As noted above, even the military authorities did not fully understand how to use them. Usually, in the early days, they were sent "over the top" after an intense bombardment, which created a condition of terrain almost impassable for man, beast or machine. Consequently, while effective in some degree, their full value could not be attained. At Cambrai, in October, 1917, however, they had their first real chance. Here they were used in large numbers, and there was no preliminary bombardment. This fact meant surprise to the enemy and good terrain to operate on. The results were remarkable, and since then the most sceptical critic has had little to say. The subsequent reverse at Cambrai was in no wise connected with the employment of tanks. Two most interesting facts were the result of this attack. First, the saving in ammunition—which would have been used according to the old system in this one engagement—equaled the entire expense of the whole tank development up to that time. The tank squared financial accounts in this one engagement. Second, the finest, and supposedly the most impregnable, section of the famous Hindenburg line was crossed and captured with ease.

The French had been busy, too, during this period. Only a little later than the English, they started developing a tank. They completed and put into the fighting line two machines, one made by the Schneider Company, and one by St. Chamond, the former being mechanically



A 3-Ton Tank

driven, while the latter was of the gas-electric type. Both were equipped with one 75-mm. gun and several machine guns in addition. These two machines were not, however, of the type of the English tank, with its all-around track. They were practically overgrown caterpillar tractors, with the necessary equipment mounted thereon. The bodies, in each case, extended, both fore and aft, considerably beyond the ends of the track proper, and also extended over the top of the tracks. This construction imposed serious limitations on the ability of the machines to negotiate bad terrain. Like the English tanks, they were somewhat lacking in power, which, taken

together with the overhanging body features, seriously curtailed their action.

The French quickly arrived at the opinion that large tanks would not be successful, although subsequent developments with the English tank showed that in this respect they were much mistaken. In many ways, however, their decision was fortunate, in that it led them to turn their attention at once to the construction of a smaller machine. The result of this decision was the development by Louis Renault of a small two-man tank capable of considerable speed and possessed of a very fair amount of power per unit of weight. In many ways, the small Renault tank is a very remarkable machine. It will cross trenches up to 5 or 6 ft. wide. It will climb grades of one in one, or 100 per cent. It will hold a speed on a level of about 5 miles per hr.

These tanks were built of two kinds, one equipped with a 37-mm. one-pounder semi-automatic gun, and the other with a Hotchkiss machine gun. These were used in about a 50-50 ratio in actual fighting.

The tracks were spring suspended, which enabled a speed of 5 or 6 miles per hr. to be easily maintained without serious detriment to the machine. In fact, some of these machines, since equipped with more powerful engines, have successfully made 10 miles per hr. across open territory.

It is very natural that the experience of the French with their first large tank should have convinced them that the small unit was the solution of the tank problem. It was equally natural that the success of the British with their large tank should have, at first, convinced them that the big type was the solution. The results were extremely fortunate, in that they gave to the Allied fighting forces two kinds of tanks.

When the American Army entered the war both of the above lines of action were sufficiently well defined, so that the Americans decided to use both kinds, namely, a large and a small tank. For our small tank we adopted the Renault type. For our larger unit we accepted a modified design of the large British tank, the design being a production of British and American ordnance engineers working jointly in the winter of 1917-18 in London.

Certain fairly well-defined essentials have gradually appeared in the matter of tank construction. They are as follows:

(1) Not less than 10 hp. per ton of weight should be provided.

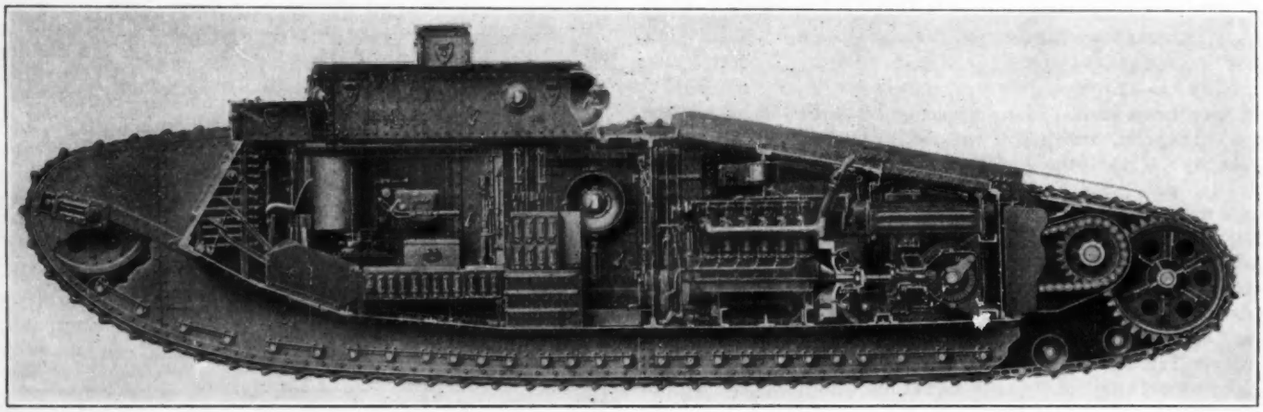
(2) The pressure per square inch between the track and the ground should not exceed 5 lb. per sq. in.

(3) The tank should be entirely controlled, so far as its mechanical operation is concerned, by one man.

(4) The tank should be capable of making a speed of not less than 5 miles per hr. on a level, and anything over that greatly increases the fighting ability of the machine.

(5) The only armor is that required to give protection against armor-piercing machine-gun ammunition.

A great deal has been said and thought about tanks with heavy armor, 2 and 3 in. thick, as a protection against moderately heavy artillery fire. Actual fighting conditions, however, have proved conclusively that tanks are rarely struck by direct artillery fire when in motion in action, as they do not present a very large target, and then only a moving one. Nearly all of the tank mortalities resulting from direct artillery hits have occurred when tanks were standing still, either awaiting orders or unable to move for mechanical reasons. Thus it has been demonstrated very conclusively that against artillery fire the best protection of the tank is its own speed and mobility and not the armor which it carries.



SIDE VIEW OF THE MARK VIII TANK

It is very doubtful whether any supertank will be of a great deal of value, although one would be rash to make too positive a prediction. Anti-tank cannon, so called, have been developed by the enemy, but have never succeeded in doing anything serious. The super-machine gun, or a heavy caliber rifle, up to perhaps ½-in. caliber, is the most serious attacking force that the tank has to defend itself against. Experiments on armor plate, however, indicate that defense against guns of this type can ultimately be secured with armor plate little thicker, if any, than that used at the present time. It might be stated here that the development and resisting power of light armor plate have recently been most gratifying, and indicate remarkable results possible in the near future.

The future development of the tank presents great possibilities. It must be fast, light on its feet, so to speak, and have large radius of action. It would appear that three sizes of tanks would be required:

First, the large one. This must be able to cross any trench that can be manned by the enemy. It is quite probable that large tanks will entirely preclude trench warfare. If so, the whole strategy of war will be changed. These large tanks will not be required in great numbers, but their presence is imperative;

THE MARK VIII TANK CLIMBING A STONE WALL

Second, a medium-sized machine for following through after the large tanks and putting up a stiff fight. These machines must be tough fighters, and be present in considerable radius of action; and

Third, a small machine that will carry a driver and one gunner. It must be as small as possible to carry the two men. It must be simple in construction and very fast. It should be used in vast numbers, and be, in fact, a mechanical machine-gun cavalry. A thousand of these machines breaking through a gap made by their big brothers would completely disorganize the enemy's rear and produce a disaster.

In closing, let me repeat: The tank is one of the few new things produced by the present war. It is only in the nursing-bottle stage. It will work a complete revolution in methods of making war. The side having the largest number of good fast tanks of the correct kind will always win. Its development has been almost a romance, and the future contains vastly more for it than the past.

THE DISCUSSION

CHESTER S. RICKER:—At what speed were the 35-ton tanks of the Mark VII type supposed to operate? Their horsepower per ton was very much in excess of the figure which you suggest as desirable. Was this excess used to gain speed or to increase the mobility of the unit?

LIEUT.-COL. H. W. ALDEN:—The Mark VIII tanks were to operate at 5½ miles per hr. with the engine running at 1400 r.p.m. The horsepower which I stated as being desirable was at least 10 hp. per ton of weight. These tanks weigh about 35 tons and the engine will develop about 350 hp. Consequently the ratio is about what I gave.

MR. RICKER:—Are not the stresses imposed upon the framework of the large type tank enough to wrench it until it becomes loose? I appreciate that the design of these machines employs the armor plate that forms the hull as the main framework upon which the mechanism and track are mounted. It would seem that in crossing trenches or shell craters diagonally the box-shaped frame would be twisted just like a cardboard box heavily weighted and suspended at two points. It would tend to buckle. Under these stresses how long do the tanks last in service when they are not destroyed by direct hits?

LIEUT.-COL. ALDEN:—Very severe tests were made on this tank to determine distortion. It was jacked up and balanced at the center; it was jacked up at two extreme ends, and it was jacked up at opposite corners, and practically no deflection or deformation could be found. There is no reason why the life of these tanks, due to this particular feature, should not be practically indefinite.

MR. RICKER:—With the hull type of design, which I note has been used by the British not only on their tanks but also on their towing and load-carrying tractors, is there greater immunity from loading of the track and the subsequent breakage such as is encountered on tractors of the more open type of track support? The military tractors that employ the track frame like the 5-ton model and also the spring-supported tracks like those on the 6-ton special tank had considerable trouble from track breakage when going over gravel or similar terrain. How did the breakage of track on these compare with that on the hull-type tanks in which there seems to be almost no chance of track loading?

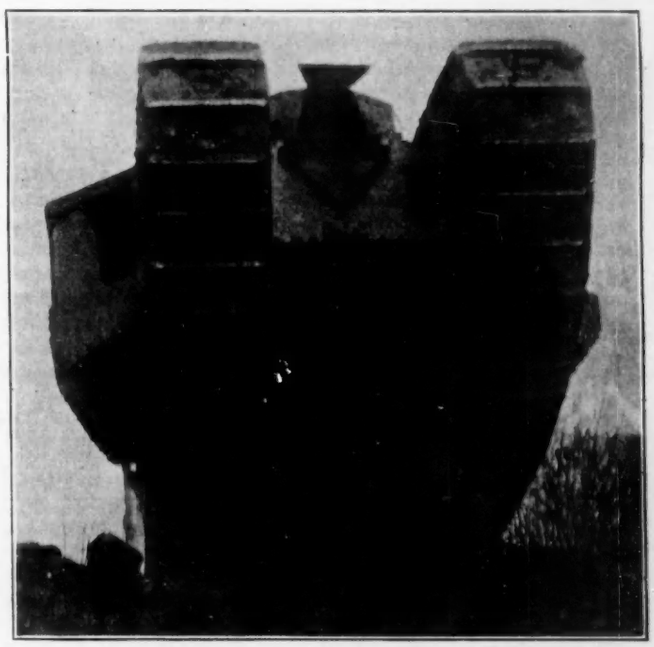
LIEUT.-COL. ALDEN:—In regard to breakage of tracks, it can be stated that the British had considerable difficulty. Their tracks, however, were made of steel castings riveted to pressed steel shoes, and the steel castings wore out. Track links on the Mark VII machine were heat-treated forgings, and the model machine, which ran something like 100 miles on a hard surface, showed absolutely no wear. It was run over rocks at full speed to break the track, if possible, but no damage resulted.

MR. RICKER:—What were the difficulties encountered with the gas-electric machines? On account of the large reduction necessary between the engine and the track drive sprockets it would seem that there might be a decided advantage in the electric drive.

LIEUT.-COL. ALDEN:—The difficulty with the gas-electric system of propulsion is that it has not the quickness of response, the necessary punch and the necessary efficiency at extreme overloads. There is no difficulty in getting the requisite gear reduction mechanically, and the total weight of the transmission is very much less with the mechanical than with the gas electric.

MR. RICKER:—How were the electric machines controlled? Were separate controllers used for each track like the separate clutches used on the Renault type tank or planetary gearing as on the large tanks?

LIEUT.-COL. ALDEN:—Special switches and controllers were used on our experimental machines for each track.



A FRONT VIEW OF THE MARK VIII TANK CLIMBING

MR. RICKER:—How much faster were the tanks with the spring-supported track rollers of the Renault design than those with the non-spring-supported track rollers on the hulls of the large tanks? I have noticed that in the tractor field the tendency has been away from the completely articulated track like Renault and toward the English rigid type. In one very long unit, the Mark VII tractor caisson, three track roller frames were used and then abandoned in favor of one very long one and a short one, combined or connected with a hinge. Also Schneider seemed to consider the single rigid track frame more desirable than the Renault type. Which, in your experience, seems to be the better, or is there some particular field in which one works better than the other?

LIEUT.-COL. ALDEN:—There is no question but that very high speed necessitates spring suspension of some type. Adequately suspended on a peculiar form of spring suspension, a certain heavy English tank was actually driven on a highway at 28 miles per hr. without any damage. This, of course, is an extreme case, but I believe that where the speeds exceed 5 or 6 miles per hr. it is necessary to have a spring-suspended roller.

BELLEAU WOOD

SOME of the Germans had almost reached the main Paris road when they met the Americans. I saw their graves very close to the road. Our boys told me that on that fateful early morning they ran into an enemy advance column tramping down the valley with their packs on their backs and singing as though they had a free road to Paris. But with a whoop and a cheer the American "devil dogs" were after them like hounds after rabbits. They fought them from behind trees, ridges and culverts. By night of the first day the Germans were driven back into Belleau Wood and 500 of them were taken prisoners. Then in 23 successive days and nights of terrible, thrilling combat, the enemy was dislodged from his fastnesses, made prisoner or killed as the marines attacked, steadily and furiously, with a spirit that would not brook defeat. In furious and perhaps the first real open fighting, the Boche was driven back.

It was on June 1 that the marines took up the support line with the French troops, hard pressed by the Boche holding the line out in front. The presence of the Americans greatly sustained and encouraged the French, some of whom had been fighting without food for 4 days and almost without water. They were completely exhausted. It is true that the Germans had also been in almost constant battle. But they were victorious and advancing. That made all the difference in the world. For the next 3 days there were constant fighting, artillery fire and machine-gun attacks. But on the morning of June 4 the Americans took over from the French 12 miles of front. This was the whole apex of the German wedge toward Paris.

Preceding the attack on the wood itself we fired 30,000 shells into the wood within an hour. Imagine what it must have been to have plunged into that reeking jungle alive with the enemy, lying behind trees, rocks and crevices and hidden in dugouts beneath the ground. Amid the roar of guns, the shouts and cries of men, the "devil hounds" advanced, digging themselves in as they went. They kept pushing forward, improving their positions, often working past the concealed machine-gun nests so that the enemy was behind, before and on either side. As the Germans kept pouring into the forest they put on the uniforms of dead Americans. It was hard to tell, at times, who was friend or foe.

Belleau Wood, which had been desperate enough, had become a living hell hole. The open wheat fields surrounding the woods were swept by shell fire and also by machine-gun fire from nearby woods. The line of communications into the wood was a center of bombardment. It was necessary to pass through a hail of death to get ammunition, rations, water and engineer stores to our troops. The enemy wished to maroon the Americans. The splatter of machine-gun bullets in the wheat fields raised clouds of dust that looked like a stubble fire.

In the wood the fighting continued for days and nights seemingly without end. Officers and men became isolated from their commands. They fought in little squads.

The marines stopped at nothing and always went forward to the attack, usually carrying their objective before they were expected to. The first attack upon Bouresches did not bring the entire Belleau Wood into our possession, but it gave us about half of it, and put us in better position to clear it all. Meanwhile the division was holding the line everywhere, and in some places actually gaining, hands down.

Meanwhile the fighting was maintained with undiminished intensity. It would have ended in a deadlock had the marines been content merely to hold their ground. It was impossible to outflank all the German gunners whose machine-gun nests extended across the wood. The nests had to be taken by assault. Time after time the marines charged the guns and death took its toll. Battalions were cut to fragments. The survivors consolidated and went back into the fight. On the night of June 8, at 10:30 o'clock, 213 replacement troops marched past the lines under detail from regimental headquarters. They were met by platoon guides and conducted to their stations. Shells striking the tree tops exploded. The crashing of branches, the flash of flame, the thick clouds of stifling dust thrown in air by impact of steel created an indescribable scene. The mighty German armies which were employing three full divisions to hold this strong point were being beaten back by a handful of marines.

The first assault had given the marines one-third of the woods. Then had followed the capture of Bouresches and they pushed forward until they had taken one-half the woods. Then in a fresh assault on the northern part they took two-thirds of the northern half and many machine guns and prisoners. In the remaining one-third of the northern part the Germans were heavily fortified with machine-gun nests and hidden away among the boulders.

Before the end of the second week in June the enemy made a desperate attempt to recapture Bouresches. They began with a terrific bombardment, sending their men forward behind the barrage. Some of the enemy reached the outskirts of the village and died there. Enemy reserves also seeped into Belleau Wood and dug in, planning to hold their ground despite the most determined opposition.

But the marines held on in Belleau for a good two weeks. Along about June 21 and 22 a regiment of regulars, which had been brought in to relieve the hard-pressed marines, tried to capture the remaining third of the north end. The attempt failed. The marines were brought back. They tried again and failed. Then the strong point was subjected to a terrible last American bombardment. Following this they again attacked the position and all of the Bois De Belleau came into American hands.

It had taken 23 days to dislodge the enemy. Time after time he had sent his legions into the wood. There is not, French authorities have told me, a record of more gallant and desperate resistance in the whole war than that made by the marines. At times the Germans outnumbered the marines at odds of five or six to one.

The fighting in the Bois de Belleau makes one of the most glorious and heroic records in American history.

—H. M. Wright.

The Next Step in Agricultural Implement Design

By E. A. White[1] (*Non-Member*) Tractor Meeting Paper

THE trying period through which this nation has just passed again brought the fundamental importance of agriculture to the attention of every thinking man and woman in a most forcible manner. It has been a time which has caused the essentials of our national life to stand out against a great background of things, many of them very desirable, but which are not absolutely necessary to the peace, happiness, and prosperity of the people of this great nation.

In the front rank of these essentials stands agricultural machinery. So essential is this equipment that national war boards with almost unlimited authority showed no hesitation whatsoever in classifying it next in importance to the munitions of war. With the outcome of the world war definitely settled, we find ourselves today in a transition period. We face a dividing of the way, and the decision must be made whether we are to settle back into the old method of doing things or take cognizance of the many new opportunities presented, and strive onward to greater achievements. No true American will hesitate for a moment in making this decision. We are going to strive for greater achievements, and it is to be hoped that the agricultural implement industry will be one of the leaders in this respect. Under these conditions it is of the utmost importance to discern, if possible, what the next great step in the design of agricultural implements and machinery should be. To get a perspective it may be desirable to review briefly the methods by which our agricultural machines have been brought to their present stage of development.

Development of Agricultural Implements

Practically all of our important implements, such as the plow, harrow, grain binder, mower, corn planter, grain drill, etc., were invented and perfected by men who possessed genius, vision and courage in a marked degree, but who were generally without technical training. These men knew every detail of the conditions to be met. Many of them were farmers, or at least had grown up in agricultural surroundings. This gave them the background for their wonderful achievements. Nothing we can do will add to or detract from their greatness. Their monuments are all about us, in the form of practical machines which relieve mankind from much of the drudgery of hand work, and enable us to produce food for millions of hungry people. What better memorials could these men have left for succeeding generations?

As "nothing succeeds like success," it is but natural that the methods of these pioneers should be followed. As a result, we are today still developing and perfecting our implements by cut-and-dried methods. To sum up the situation, we can truly say that our machines have been, and still are, developed by empirical methods. Certainly we are not going to rest on the oars and let this generation pass without contributing something of real worth to the design of agricultural implements. We will be unworthy of the rich heritage which is ours if we do not act. We will find ourselves out of harmony with the spirit of the time in which we live if we take as our motto "Present methods are sufficient." Are we to admit that the day of dreams and visions is past? Certainly there will come from this generation a group of men worthy to follow in the footsteps of Deere, Oliver, McCormick, Deering, Avery, Appleby, and others, men who are designers of agricultural machinery. Any one, I believe, who is familiar with the situation will admit that empirical design has been brought very near to a maximum stage of development. We have enlarged our experimental departments, carried on development work in all sections of the country, achieving truly wonderful results, but the fact remains that through all this work we have brought forth very few fundamental theories which will serve as a basis for design. Today we have no theories for the moldboard and the oscillating sickle, two of the most fundamental mechanisms upon which the agricultural implement industry has been built. Further than this, stress and strain diagrams have never been developed which show whether the members of our heavy tillage implements are subject to compression, tension or twisting strains, and the mechanisms of such machines as the binder have never been analyzed on the basis of the well-known principles of kinematics. At least, if this work is being done, I have been unable to find it.

Necessity for Scientific Designing

As a result, we are today developing machines for a new mechanical motor, the gas tractor, by the same methods which have been used for the past 50 or 75 yr. Under these conditions is it not logical to believe that the next step in agricultural implement design will be to supplement empirical methods by scientific ones? Today we are wrestling with the questions of increased velocity, the coordinating of the implements and the tractor, the value of push machines, especially for harvesting work, and the possibilities of developing absolutely new machines for soil preparation and tillage work. What a great help it would be if we had theories for our machines, and if present constructions and mechanisms were completely analyzed from the standpoint of mechanics and kinematics? Such work has already been done in other great industries. We have theories for the design of electric motors, magnetos and steam and gas engines, and companies producing this equipment have well-established research departments which act in close cooperation on all experimental work. In fact, the research departments very frequently furnish the initiative for new lines of development. There is a great literature already in existence to which designers can turn for information upon electrical machinery, steam or gas engines, but when one searches the written pages for the fundamentals of agricultural machinery design he returns empty handed. It is certainly to be expected that we cannot afford to continue in this manner.

Other industries have furnished conclusive evidence regarding the value of scientific work. Their present

[1]Department of farm mechanics, University of Illinois, Urbana, Ill.

developments would have been absolutely impossible without such work. It now remains for the agricultural implement industry, one of the greatest and most important in the world, to develop the science of agricultural implement design. In the first place, this will mean the establishment of research departments by our leading manufacturers. The progress at first will be slow, but the ultimate results correspondingly great. These departments would not only collect a great wealth of indispensable information, but their work would ultimately place the agricultural implement industry on a scientific plane, which would command the respect and admiration of laymen and professional engineers, as well as all others interested.

NEED FOR GOOD ROADS

NEVER in the history of this country have good roads been so much needed as at the present time. The enforced neglect during the period of the war has caused many of our roads to fall into a bad state of repair, and many of them have failed altogether. The immediate future will see an ever-increasing traffic, and our roads will be depended upon to bear weights and speeds that will sorely try them unless they are put into such a condition as will withstand the great wear and tear to which they will be subjected.

What are the main points to be considered in order to make our roads capable of performing this duty?

A good road should naturally be of sufficient width to carry all the traffic that is likely to make use of it, and intelligent forecasts must be made when designing a new road, or in widening and improving an old one.

The proper camber of a road is of importance, since when too severe it leads to the skidding of motor vehicles and side-slipping of horses, besides tending to throw all the traffic to the center of the road. The object of camber is only to give a quick "run-off" to the rainwater falling on the surface, and it is frequently more than is needed and should be reduced. For a good road the following table of suggested cambers is given:

Good Foundation Required

Natural rock asphalt	1 in 60
Wood pavement	1 in 50
Granite or similar sets	1 in 50
Artificial asphalt carpets	1 in 48
Tar macadam and tar slag	1 in 45
Ordinary macadam tar sprayed	1 in 40
Ordinary water-bound macadam	1 in 36

Before dealing with the question of materials and the manner in which a good road should be constructed, the all-important question of the foundation must be considered, as it is this which carries the weight of the traffic. Many of the failures of our roads are due to the lack of this essential provision. Nor must it be forgotten that water is almost as great an enemy to the life of a road as excessive traffic, and that, unless the foundation is properly drained, damage must eventually result.

Local conditions must guide the road builders as to the procedure to be adopted. A good artificial foundation for stone sets, wood blocks, or natural rock asphalt is made of reinforced Portland cement concrete as thick as the extent and weight of the traffic and the nature of the subsoil demand. For all artificial asphalt and bituminous-bound macadam roads the foundation should either be of some similar resilient construction, or of the type known as the "Telford," which may be described as follows:

Upon the natural bed, prepared to the proper contour, a layer of stones with their largest side down is set by hand, breaking joints as much as possible, but set closely together. Interstices are filled with smaller stones, and the whole structure is well rammed or rolled. The advantage of such a foundation is that it permits water to run through it, and in a pervious soil, no better drainage is required; but where the soil is impervious, special provision must be made at the sides of the road to carry off the water.

It is curious to note in connection with Telford's foundation that some of the roads he constructed have been opened and no such foundation has been found! Possibly the turnpike trustees at that date were alarmed at the expense and curtailed the foundation, or Telford himself may have thought it unnecessary to provide such a foundation in all cases, and we are unfortunately enduring the result of this cheeseparing. Where our roads have been constructed with proper foundations, even the ordinary water-bound macadam has withstood the traffic in a remarkable manner, and where surfaces have been maintained and have been tar-sprayed or tar painted, they have shown excellent results.

Materials Employed

The next point is the question of the materials to be employed, and the method of constructing the upper crusts and surface of the carriageway. This always requires a careful study of the amount and description of the traffic the road will have to bear, local surroundings, gradients, climate, and a number of other considerations. It would be as absurd to pave a residential street with granite sets as to try to maintain an ordinary water-bound macadam road in a busy manufacturing town, or on a stretch where a fleet of motor omnibuses or commercial vehicles constantly made use of it. Cost of construction should not be held important, provided that value for the money is received. An economically constructed road may prove to be much dearer in the end, owing to cost of maintenance. To be penny wise and pound foolish has unfortunately been the practice in the past with regard to our roads, and it is to be hoped that this will be stopped when the changes in road control now contemplated by the Government come into effect.

Dealing with present known methods of road construction in the order of the intensity and weight of the traffic to which they are likely to be subjected, the following is a short description of some of the methods adopted:

Granite, and other hard stone sets should be so dressed that they can be laid close-jointed, to minimize noise and facilitate cleansing. They should be laid on a bed of reinforced concrete grouted with a hot bituminous mixture.

Wood blocks should have a similar foundation, be close-jointed but with expansion joints at the sides of the road to provide for the swelling of wood under moisture. To minimize this effect and to prolong their life, soft wood blocks should be impregnated with creosote or similar oil, not less than 10 lb. of creosote oil per cu. ft. of wood.

Durax consists of small random stone cubes laid close-jointed and grouted in the same manner as granite sets. Much of the failure of this class of paving has been due to the lack of a rigid foundation and the neglect of proper grouting.

Although in America and in some of our Colonies many millions of square yards of concrete road have been constructed, hitherto in this country only a few thousand square yards have been laid. The objections to this description of road seem to be (1) that traffic must be diverted from it for some weeks after construction; (2) it is liable to crack if not very carefully constructed and reinforced; (3) it needs very close supervision during construction; (4) it is not a very cheap form of construction in the first place unless laid on a large area, with well thought out appliances for economizing labor.—H. P. Boulnois in *Motor Traction* (London).

GAGING THREADED PARTS FOR AIRPLANE WORK

COL. R. E. CROMPTON, a member of the British Informal Correspondence Committee, affiliated with the British Engineering Standards Association, has sent the following memorandum to E. H. Ehrman, chairman of the Miscellaneous Division, S. A. E. Standards Committee and a member of the American branch of the committee. The memorandum, which is presented substantially in full, gives the results of the experience of the British along this line.

It is well understood that the gaging of screws differs from the gaging of ordinary cylindrical parts, as the gages required to insure the accuracy of the threaded surfaces have to deal simultaneously with two dimensions, i.e., pitch, which is a length dimension, as well as diameter, whereas the ordinary limit gages deal with diameter only. This has made it a difficult matter to gage screws by the ordinary limit "Go" and "Not-go" gage system which is universal for the gaging of cylindrical surfaces. Although many attempts have been made to produce threaded limit gages and all the gages supplied to the Government departments have been of this nature, it cannot be said that their use enables an inspector to gage screws such as those used for airplane engines in quantity with any degree of accuracy, and I propose that the alternative method of gaging only a part of the screws forming the output of any firm be substituted for the present method, at any rate for close fits.

Difficulties of Present System

The only recognized gages for the effective diameter which is the dimension of the screw to be measured and which alone is the cause of our difficulties are

(1) Standard full thread form plug for gaging nuts
(2) Full thread form solid ring for gaging bolts or male threaded work

Even if these are altered by truncating the crests of the male gage and giving clearance at both crests and roots of the ring gage, these gages tell us nothing about pitch error, and difficulties always arise from wear of the gages themselves. Both gages can be used as "Go" gages up to a limited number of screws passed through them, but a point is soon reached at which the plug becomes so worn as to pass nuts smaller than the required dimension, and similarly the worn ring gage passes male screws larger than those it passed when it was new, so that the wear of the two gages prevents the nuts and bolts from assembling. It was one of the objects of introducing allowance in the British Engineering Standards Association's Report No. 84 to provide for the wear of these fixed gages. As yet there are no effective "Not-go" gages by which the inspector can refuse work that, although it passes the "Go" gages and can be assembled, is nevertheless too slack a fit to be suitable for good work.

All systems of "Not-go" gaging are slow in working, so that their use must be confined to gaging selections from any batch of screws offered to the inspector. The only method that I am aware of that obtains reasonably accurate fit combined with interchangeability has been the optical methods which have been used on a large scale at Woolwich Arsenal, Farnborough and elsewhere, and which have undoubtedly given good results, but up to the present few manufacturers have been able to obtain the optical apparatus necessary, and as it is not portable inspectors have been able to avail themselves of it only in the few cases where the threaded work is inspected in bulk at large receiving centers.

Tap Inspection as a Substitute

I submit, therefore, that for the future the best results will be obtained by not attempting to pass all screws through "Go" gages but by adopting a system of inspecting the taps used for the nuts and the method of using them so that the nuts produced by the inspected taps, when carefully used, will be so correct to standard that it will be unnecessary to gage the nuts themselves in quantity. The Engineering Standards Association has appointed a tap panel which has been sitting some time and has produced a specification for standard forms of taps. A number of these are to be ordered for experimental purposes. They are to be tested to the point at which the tap should be destroyed as no longer tapping nuts within the limits laid down in Report No. 84. There appears to be little doubt that the introduction of these standard taps when passed through all the nuts in a workmanlike manner will insure close fits and that the staff required to pass nuts and stud holes can be reduced, although the quality of the work will be higher.

As regards the male screws, bolts, etc., it would be well to consider thoroughly and test a system of inspecting only a part of the screws as they leave the forming tools at the maker's works; in other words, the inspectors would satisfy themselves that the forming tools are always in order and are thrown out of use for the dies to be reset after the wear has reached a certain point. As to the methods of gaging the selected male screws, the full and core diameters present no difficulties, but for gaging the effective diameter of bolts, male screws and taps, apart from the needle method of measuring the effective diameter of one thread, which is not suitable for passing threaded work in quantity, inspectors now can have the choice of measuring the effective diameter of both male screws and female screws by two methods.

By method A, which we will call the split-nut method, the two halves of a carefully made split nut are applied to the male screw to be measured and by observing the outside diameter on a ground bolt immediately outside the threaded work, which outside diameter bears a definite relation to the effective diameter of a standard gage, the effective diameter of any screw can be compared with that of the standard. Several forms of these split-nut gages are now available. The same method can be applied also to the taps and the results thus obtained are found to be far more concordant with the effective diameter measurement of the nuts tapped than is the case when the taps are measured by needle.

Method B, which for convenience I will call Price's method, can be applied to either female or male screws. Price's gage to measure female screws consists of a pair of carefully ground hardened disks, each of which is an exact full form male thread. These two disks are mounted on an axis so that one of them can be revolved in relation to the other, the distance between them being a multiple of the pitch. If, for instance, it is desired to measure ½-in. nuts, eight-thread engagement, it is convenient that the Price disks should be spaced six threads apart. After the nut to be measured is screwed over the two disks, by rotating one of them and observing the angle of rotation on a suitably placed scale, the amount that the pitch differs from that of the standard ring gage can be observed; whether the pitch is long or short can also be shown at one reading, and by doubling this pitch error we at once get the amount by which the effective diameter of the nut is larger than the nominal. Again, by using two rings, each consisting of only one female thread and mounting them similarly to the first described gage, the pitch, the direction of pitch error and the effective diameter of male screws or of taps can be measured.

By using method B we gain two things. In the first place, the disks can be made from previously hardened steel blanks by grinding to correct form so that extreme accuracy can be obtained at low cost. The wear on the disks or on the female rings is small because they are a slack fit when put on the work to be tested, and until one of the disks is rotated to ascertain the pitch there ought to be practically no wear. In practice it is found that the speed of working is very high; upward of six nuts or six bolts can be tested per minute, and at each reading three points of error can be ascertained, the pitch, its direction and the effective diameter. In fact, I found that the speed of working is four times that in using the ordinary plug and ring gages.

Vol. IV May, 1919 No. 5

Aircraft War Activities of Forest Products Laboratory

By CLYDE H. TEESDALE[1] (*Non-Member*)

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

FOR 10 yr. prior to the war the Forest Products Laboratory, a branch of the Forest Service, United States Department of Agriculture, had been engaged in investigative and industrial research work on wood, wood products and related elements. This work had included mechanical strength tests of wood, kiln drying, wood identification, structural studies and investigations of the problems of the wood, chemical, wood preservation and pulp and paper industries.

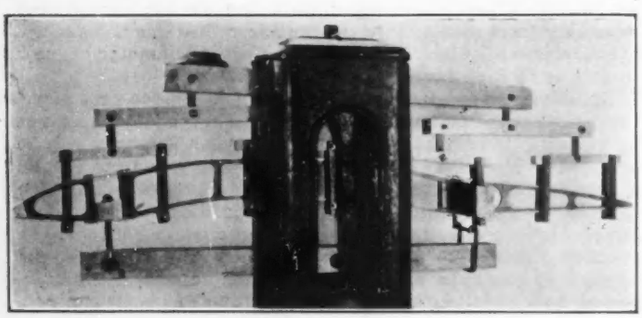
Upon the outbreak of war, the trained personnel and the facilities and equipment of the laboratory were made available to the Army and Navy. Information on many phases of the wartime uses of wood were, however, not available, and a steady expansion of both personnel and equipment took place to work on these problems. The extent of this is illustrated by the fact that eighty-five people were employed at the start of the war, while at the end the organization numbered about 450. This increase was largely financed by the Army and Navy. Much of this expansion was in studies directly concerned with the requirements of aircraft for wood.

RAPID DRYING OF SPRUCE

One of the first problems presented was the drying of spruce. The Allies had drained the country of air-dried spruce and none but green stock was left for us. We could not wait for the slow process of air-drying, and no method of kiln-drying was known that would with certainty retain the desirable strength properties of air-dried spruce. The laboratory worked out kiln-drying methods which were demonstrated to give material of equal if not superior properties to air-dried stock. Similar work was done on other species used in airplanes.

STRENGTH OF AIRPLANE WOODS DETERMINED

The strength properties of airplane woods needed much study, as the available data were incomplete. Much stress was given to work on spiral and cross grain, and detailed information is now available on the extent to which such defects are permissible in airplane parts.



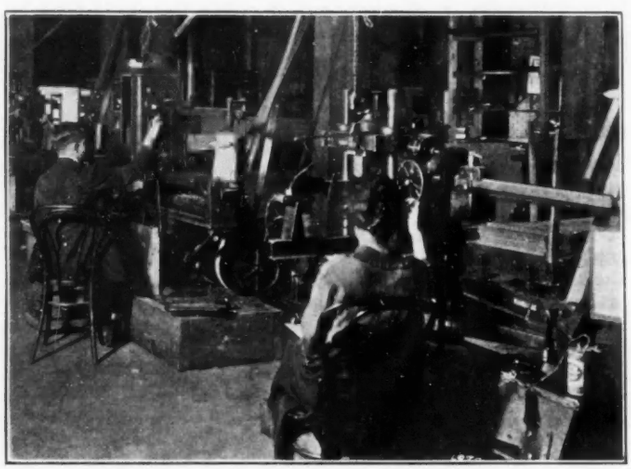
TESTING AN AIRPLANE RIB

Other defects were studied and specifications prepared showing the extent to which it is permissible to allow material with defects to be used and the correct locations. Methods of splicing and laminating airplane parts were studied, an example being the adoption of specifications permitting the use of spliced and built-up wing beams.

Several new designs of wing ribs were developed, one for the DH-4 machine giving double the strength of the old one with 70 per cent of the weight.

IMPORTANT WORK ON PROPELLERS

Heavy rejections of airplane propellers because of checking, twisting, warping, etc., demonstrated the need for accurate data on built-up or laminated constructions. It was known that these difficulties were partly due to unequal shrinkage and swelling in the laminations, be-



A PORTION OF THE TIMBER MECHANICS' LABORATORY

cause of unequal density and moisture content. A department was organized to study this problem and is working out methods of preparing and handling wood that will eliminate much of the trouble experienced in wood propellers arising from improper conditions surrounding their manufacture. A practically waterproof coating was developed that will make propellers largely immune from sudden or great atmospheric changes while held in storage.

NEW PROBLEMS IN PLYWOOD SOLVED

The extensive development of the use of plywood in airplanes brought about many new problems. Plywood had never before been put to such exacting use, and little was known of its strength properties. Data were developed, however, and there is now available for numerous combinations of species and thickness a rather complete knowledge of plywood as a structural material.

[1]Section of wood preservation, Forest Products Laboratory, Madison, Wis.

THE PROPELLER LABORATORY

Aircraft also demanded waterproof plywood, a product practically unknown in this country before the war. Formulas for waterproof glue, methods of testing glues and plywood, and specifications were developed at the laboratory. Similar work was done on animal glues, the object being to secure a product satisfactory for airplane propellers.

Cooperation existed between the laboratory and various branches of the Army and Navy in the production of wood charcoal for gas masks, development of a wood pulp suitable for nitro cellulose, studies of boxes and containers, especially for overseas shipments, specifications for wood for wooden ships and a long list of minor activities.

SOME APPLICATION OF WAR WORK RESULTS

Much of the work done is of interest and value to wood-using industries and will probably soon be made available to them. Of particular interest to the S. A. E., aside from the data compiled on the use of wood in airplanes, should be the possible development of veneer and plywood construction in automobiles, wherein success may be achieved through the use of waterproof glues. Bodies made of waterproof plywood boiled in water and pressed in molds are commercially possible today.

Waterproof glues will also make possible the use of built-up or laminated parts that were not feasible hitherto because they would not stand unfavorable weather conditions.

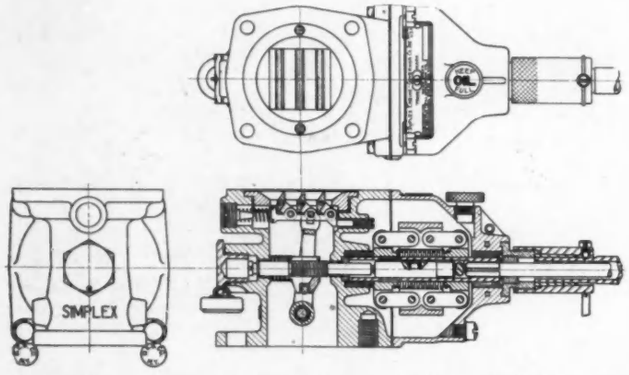
It seems likely that development work on aircraft designs will continue and make necessary the continuance of many features of the wartime work of the Forest Products Laboratory. The application of this work to industry also makes it seem still more likely that it will continue on a scale which will be considerably greater than was the case before the war.

The Simplex Tractor Valve

By THEODORE DOUGLAS[1] (*Member*)

MINNEAPOLIS SECTION PAPER *Illustrated with* CHART AND DRAWING

THE grid valve which has been employed in the Duplex and Simplex models of governors for internal-combustion engines was designed with a view to increased efficiency over valves then in use for similar purposes. Experience with this valve, extending over a period of 4 yr. and covering approximately 45,000 installations on trucks, marine engines, generator



DETAILS OF A GOVERNOR FOR TRACTOR ENGINES IN WHICH THE MOTION OF THREE SHUTTERS THROUGH AN ANGLE OF 60 DEG. PROVIDES THE CONTROL OF THE THROTTLE-VALVE

sets and tractors, has more than justified the claims originally made for the design. Tests of these governors have been made in the laboratories of almost all the large engine builders in the United States with a view to determining the characteristics of the valve action, and the efficiency in general of the governor design.

Three points have been particularly noticeable in these results and may be found in varying degrees in all the tests conducted. They are as follows:

(1) Increase in torque of the engine when operated with the governor as compared with the torque when operated without the governor. This increase in torque results from better mixing of the ingredients of the fuel as a result of the valve construction. Each opening in the valve constitutes an elongated venturi, the principles underlying the action of which are well known. The mixture as it passes through these openings acquires a high velocity. The tendency of the ingredients to lag at the point of maximum stricture probably varies directly as their specific gravities. The on-rushing air with its higher velocity carries the fuel with it, and any particles which may still be in globular form are, through attrition upon each other, broken up or pulverized. After having passed this point of maximum stricture the fuel passes through an area of increasing cross-section, which results in a drop in pressure and produces a tendency to a fan-shaped divergence of the air currents. Each opening produces its elongated fan of fuel. These fans overlap and interlace, the air current of one meeting the air currents of the other at an angle of about 25 deg. This produces a further breaking up of the fuel particles through attrition. The net result of this action is a better mixing of the fuel and air, which when finally ignited in the cylinder of the engine burns faster, with a resultant higher mean effective pressure.

(2) Owing to the conditions favorable to a higher thermal efficiency, as indicated in (1), a higher fuel efficiency results.

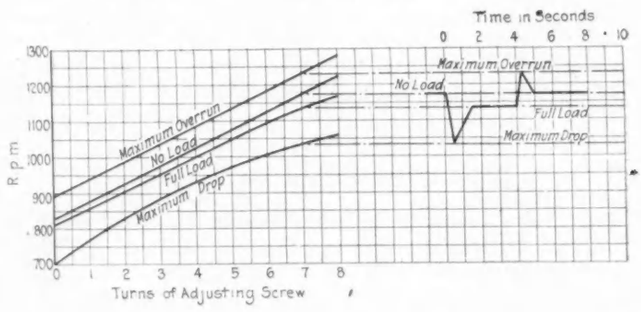
(3) The amount of angular traverse required of the moving valve member in traveling from the extreme position of full-open to full-closed valve and vice versa, is short, varying in different governor sizes from approximately 1/16 to 1/7 in. From this design there results the possibility of approximately full-open valve to within a few revolutions of the engine speed for which the governor may be set, and at which the valve should close, thus giving approximately full throttle up to almost the moment of cut-off.

Despite the high efficiency and general excellence of the construction described there seemed a possibility that for tractor service, where the atmosphere is heavily charged with dust, fragments of straw, chaff, etc., and where air cleaners are not always used, this material might accumulate below the valve and thus interfere with its effective operation. Although this condition did not develop in practice during the season of 1918, a new design was undertaken to meet the special requirements of a governor valve for tractor service specifically.

The design referred to and designed as a shutter valve, has been under consideration and in process of development since 1912, when the valve was first used experimentally with a Duplex governor. This construction is shown and, as will be noted, consists of a series of three shutters, the angular traverse of which, from the full-open to the full-closed position, is approximately 60 deg. This design, though not as efficient, incorporates many of the advantages of the grid valve with the elimination of the one possible objection to the use of that valve structure in tractor service.

The shutter valve is interchangeable with the grid valve on all Simplex models. The grid valve is recommended for every kind of governor service because of its high efficiency. The other elements entering into the tractor governor construction are identical with those of the standard Simplex governor, and are interchangeable.

The accompanying curves are shown to visualize the



CURVE OF TEST RESULTS OF A RECENTLY DEVELOPED TRACTOR GOVERNOR USING A SHUTTER VALVE

[1]President, Duplex Engine Governor Co., Brooklyn, N. Y.

operation of the shutter valve. Starting with the curve of No Load, the engine then running under governor control with the valve approximately closed, the full load of the engine is thrown on with a drop in engine speed to the curve showing Maximum Drop, the engine then recovering speed to the curve of Full Load. The engine operates for a moment under full load, which is then thrown off with a rise in engine speed to the curve of Maximum Overrun, and then a drop to the curve of No Load. The time interval of this cycle is also shown. Starting with zero time the full load is applied, the time interval as between the moment of applying the load and the maximum drop is shown as ½ sec., with recovery to full load in 1 sec. This load is carried for 2½ sec., the load being then released with a maximum overrun of 1/3 sec. and recovery to the no-load position in 2/3 sec.

The linkage and the valve members are of non-corrosive material and of substantial construction in every way. Production plans are under way for four governor sizes, the classification being based on an engine speed of 1000 r.p.m.

Model	Piston displacement, cu. in.
U	200
V	300
W	600
X	1200

The figures in the second column of the accompanying table are the maximum sizes of engine with which the governor can be used.

The Discussion

J. E. Simonds:—The mechanical operation of the valve can be explained very simply. There are three lattices and the tendency of these is to always remain open until the force generated by the centrifugal unit shall have overcome a spring-load out on one side of the valve. The centrifugal unit consists of four weights, mounted on toggles, these toggles being anchored on a block which is mounted rigidly on the centrifugal shaft. On one end of the centrifugal shaft is a sliding collar. Through this movable collar is a transverse member which engages a floating pin within the hollow centrifugal shaft. When speed is imparted to the centrifugal unit these weights expand and 70 per cent of the total force created thereby is absorbed by the spring of the centrifugal unit. When through centrifugal force this spring is compressed, the floating pin is carried forward by the sliding collar and comes into contact with an adjusting screw which runs through to the pin, the adjustment being made with the front end of the governor. As that comes in contact with the adjusting screw, it starts to compress the valve spring, constituting the other 30 per cent. When this last 30 per cent of pressure is imparted, the shutters begin to close, and the last fifty revolutions then serve to close the valve.

The closing of the valve is equally simple, as will be seen by referring to the curves. The second curve, reading from the top down, represents "no load," and we will take it at 1100 r.p.m. When the full load is thrown on the engine, the speed drops to 1040 r.p.m., and comes back to 1085 r.p.m. The third is the full-load curve, and the time required from the moment the load is thrown on until it gets back to full-load position again, is 1 1/3 sec. When the load is thrown off the engine runs up to 1190 r.p.m. and recovers in 1 sec. The time scale is laid off at the proper point on the curve, you will notice, so that at any particular point for any reading you can tell the actual time.

W. J. McVicker:—Is the time element constant?

Mr. Simonds:—Yes, within certain limits. These time tests were made with the engine running from 700 to 1250 r.p.m. There are one or two engines in tractor service operating at over 1200 r.p.m. The centrifugal elements are our standard Duplex and Simplex structures.

Chairman H. C. Buffington:—The time element looks pretty quick to me. Is this not something like a carbureter proposition? I will ask Mr. Simonds what kind of a carbureter he has.

Mr. Simonds:—The carbureter used in these tests was a Zenith 05. A governor is primarily a governor. These features of close regulation are to my way of thinking essential in a governor, while increases in efficiency which may result from its use are merely incidental. They are advantages that go with its use. The Duplex governor is not sold as an increaser of power, or as an economizer of fuel. It is sold primarily as a governor.

A Member:—I would like to ask whether in adjusting the governor to changes of speed the regulation is the same percentage on low speed as on high.

Mr. Simonds:—It would be approximately so, as our spring tensions do not change with adjustment. A one-eighth turn of the adjusting screw may mean a change of fifty revolutions on one engine, while on another with different characteristics it may mean twenty-five or sixty. If the adjusting screw were out to its maximum position so that you only just got governor control, the regulation would not be quite so close. The same thing would be true if it were at the extreme inner position. We can safely guarantee a 3 per cent regulation with the tractor valve, and still closer with the grid valve. I might add that we have dash or hand controls also laid out and have a number of them in use. The governor setting can be changed at the will of the operator from his seat to take care of varying soil conditions or other conditions which have to be met and reset at any time to the original normal operating position. It seems that in the general trend of tractor design this feature is desirable.

Chairman Buffington:—Is the governor adapted to any speed, or do you get a certain engine ratio to keep the governor at a certain speed?

Mr. Simonds:—We recommend that the governor operate between 975 and 1175 r.p.m. That should be the speed of the centrifugal unit. Anything below 975 r.p.m. would tend to make the action of the governor a little more sluggish, and getting beyond 1175 r.p.m. would cause unnecessary wear of the parts, although either higher or lower speed could be used if necessary.

A Member:—Have you ever applied the governor or used it without a carbureter butterfly?

Mr. Simonds:—I have never seen that. It would be met oftener in tractor than in truck service.

Mr. McVicker:—In which direction does the air flow?

Mr. Simonds:—With them.

A Member:—Would the governor work the same on a two-cylinder engine as on a four?

Mr. Simonds:—Not quite, but approximately so. The regulation on a two-cylinder engine is necessarily not quite as close due to the lesser number of impulses.

A Member:—With the governor set for close regulation would it not jump with each impulse?

Mr. Simonds:—No, it cannot, because the governor is designed so that the weights maintain a set position and minor shocks and variations in speed are absorbed. The governor has been worked out through exhaustive experimentation. The weights do not transmit the change immediately to the valve.

A Modified Design of Class B Truck Engine

A. F. Milbrath[1] (*Member*)

Chicago Meeting Paper *Illustrated with* Photographs

THE return to regular commercial activities after a suspension of nearly 2 yr. might naturally be expected to bring with it the embodiment of ideals developed during such a period. Development is most rapid during a time of need; the newer the science or industry, the greater the progress. Truck and tractor engine designing was no exception in this case. The advancement is naturally not as great as in the newer airplane industry, but the war period has, nevertheless, left a lasting stamp on the commercial car engine.

While reports to the contrary have appeared, statistics will show that the standard military truck engines, designed under Government stimulus in Washington some 18 months ago, were a great success, and we now find that these engines will be used in a number of commercial vehicles also.

Constructional Details

To meet the demand for such service, a 4¾ by 6 in. four-cylinder engine was designed by the company with which I am associated, combining features for durability, with a total weight, however, of about 800 lb. This has been accomplished by a judicious selection and proportioning of materials, and the adoption and adaptation of many features of design of the Government standard Class B truck.

The engines are of the L-head type, having cylinders cast in pairs, with detachable heads. The heads are secured by large properly distributed studs, so that with a copper-covered gasket, water leakage at the joint is prevented. The valves have a clear diameter of 2⅛ in. and are located on the right side of the engine. Long cast-iron valve-guides are pressed into the cylinders. A chamber formed in the side of the cylinders and enclosed by an oil-tight cover-plate, protects the valve-stems and valve tappets from dust.

The water-jackets extend slightly below the travel of the piston-head and the water space increases from about ½ in. at the lower end to above 1 in. at the top. The water enters at the lowest point on the jackets, on the side opposite the valves, so that the cylinders are self-draining through the pump. The water outlet is at the highest point on the cylinder-heads.

The crankcase is cast of aluminum in two pieces, with the parting between the upper and lower halves on the center line of the crankshaft. This construction makes all of the bearings very accessible for adjustments or repairs. A bell housing is cast integral with the crankcase and entirely encloses the flywheel. All bearings are well supported by ribs. Four through-bolts are used on each main bearing, to carry the caps, which are fitted with laminated brass shims. Through-bolts are also used for the oil-pan and front cover, where heavy gaskets are provided to make oil-tight joints. The cylinders are held down by shouldered studs with castle nuts on the inner ends.

All gears are encased in an oil-tight compartment at the front end, and by removing the front cover the camshaft, idler shaft and pump-drive shaft, with their gears, can be withdrawn.

The lower half of the crankcase contains the oil sump, which extends forward only to about the center of the engine, thus giving maximum clearance for the front axle.

A large combined breather and oil filler is fitted to the forward left side of the engine and an oil level indicator is fitted on the same side near the rear end. The crankcase is so designed that the pistons may be withdrawn from the lower side.

Use of All-Steel Support

A special feature in the design of these engines is the all-steel support. Aluminum has been dispensed with for this purpose because of the softness and low strength of this material. A cast-steel or malleable iron supporting arm is bolted to the rear face of the bell housing and a large-diameter trunnion bearing on the iron gear cover carries the forward end. This gives a three-point suspension which relieves the engine from all twisting strains. In case a unit powerplant type of transmission is used, this bolts directly to the steel rear supporting arm.

The crankshaft is of heavy construction and made of chrome nickel steel. It is 2¼ in. in diameter on the front main bearing as well as on the crankpins. The center bearing is 2 5/16 in. in diameter and the rear 2⅜ in. The front and connecting-rod bearings are 3 in. long, the center bearing 2¾ in. and the rear 4 in. The rear bearing is also provided with collars to take up all end thrust. A flange is forged integral for the mounting of the flywheel. The crankshafts are sand blasted after heat treatment to remove all scale, and the finished shafts are put into running balance. Oil holes are drilled from the main bearings to the crankpins.

Connecting-rods are 12½ in. long, of I-beam section, drop-forged of 0.35 per cent carbon steel, and are heat treated to give maximum strength. The big ends have four chrome vanadium steel bolts and are fitted with babbitt-lined bronze bushings and laminated brass shims. The upper ends are fitted with removable bronze bushings. Oil tubes are riveted to the rods to carry lubrication from the big to the upper ends.

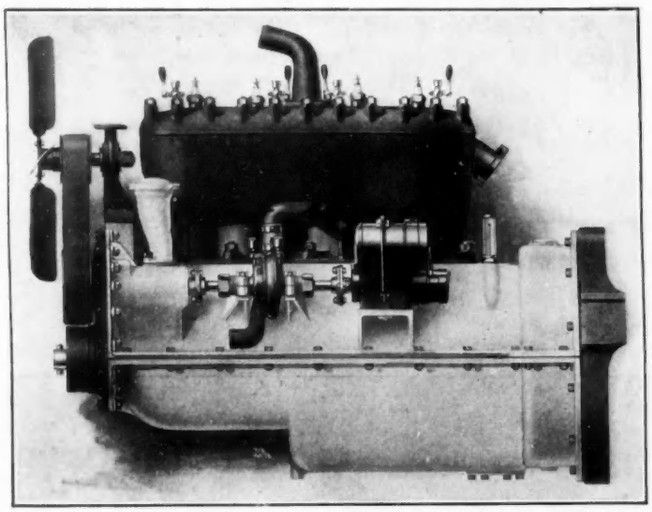
The pistons are made of cast iron, thoroughly sand blasted, machined and ground accurately to size. The heads are supported by cross ribs, two of which extend down to the piston-pin bosses. Three rings are carried at the upper, and four oil grooves at the lower end, and the pistons are relieved a short distance around the piston-pin bosses.

The piston-pins are 1⅜ in. in diameter, are turned

[1]Secretary-engineer, Wisconsin Motor Mfg. Co.

from hollow bar steel, case-hardened and ground. They are held in the pistons by lock screws which in turn are secured by special lock washers. As a precautionary measure against scoring of cylinders, split washers are sprung into the outer ends of the piston-pin bosses to prevent the protruding of the piston pins.

The camshaft is forged in one piece of 0.20 per cent carbon steel. The bearings are of large diameter so that the cams will clear when shafts are withdrawn. A flange is forged at the forward end to which the camshaft gear is attached by four through-bolts. The camshafts are held against a flange on the front bearing by a spring and



SIDE VIEW OF A RECENTLY DEVELOPED SMALL MODIFIED ARMY TRUCK ENGINE FOR COMMERCIAL USE

plunger in the front gear cover. The rear end of the camshaft carries a hardened steel helical gear for driving the vertical oil-pump shaft.

The valve tappets are 1⅛ in. in diameter, are case-hardened and carry hardened steel rollers running on hardened pins. Adjusting screws are fitted at the upper ends. The valve tappet guides are made of cast iron and are held in position in the crankcase by crab forgings and studs. By removing the crabs the entire tappet assembly may be removed.

The gears are 1¼ in. wide, with helical teeth, cut at an angle of 27¼ deg. The camshaft and idler gears are of cast iron, while the crankshaft and pump-drive-shaft gears are forged of steel. The idler gear is dished and is mounted on a shaft 1½ in. in diameter and 4 in. long, running in a babbitt-lined bronze bearing in the crankcase. Like the camshaft, the end-thrust is taken between a flange on the bearing and a spring plunger in the front gear cover.

All bearings, including the main and connecting-rod, the camshaft, idler and pump-drive-shaft bearings, are of babbitt-lined bronze. The bearings are bored and reamed in position in a fixture and the shafts then lapped in, with a power lapping machine, giving a full bearing before the engines are assembled. All bearings are properly grooved for lubrication, and the dimensions are such that bearing pressures are well within the limits of safety.

The exhaust and inlet manifolds are of iron, cast integral, so that sufficient heat will be supplied to the incoming fuel to vaporize it properly for economical carburetion. This is becoming more necessary with present heavy fuels, to reduce to a minimum the leakage of fuel by the pistons, with the resulting rapid wear of all parts of the engine due to diluted lubricating oil.

COOLING AND LUBRICATING SYSTEMS

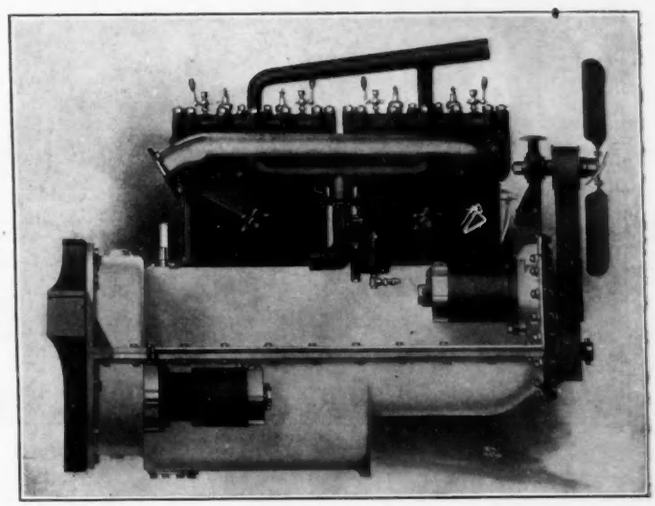
The water circulation is by a cast-iron centrifugal pump with a bronze rotor. This pump is carried in brackets cast integral with the crankcase on the left side or opposite the valves. The water pipes are carefully proportioned to the amount of water flowing at the various sections, and the circulation is designed to reach all vital points, such as the entire valve seats, exhaust ports and spark-plugs as well as cylinder-heads and barrels.

A rigid fan bracket is mounted by four studs on the front end of the crankcase, and a vertical adjustment for fan belt tension is provided. The fan belt is 2 in. wide, ample to drive an efficient fan without undue slippage and wear on the belt.

A magneto bracket is cast integral with the crankcase and is suitable for any type of magneto, either plain or with impulse starter coupling. The magneto is driven off the rear end of the water-pump shaft through a flexible coupling.

Driven off the rear end of the camshaft, a vertical shaft is provided, which may be used as a timer or governor drive. The various commercial governors on the market can be mounted on these engines.

The lubricating system is of the force-feed type. A gear pump bolted to the crankcase and extending down into the oil sump, pumps the oil under pressure to a header cast into the crankcase. From the header, leads carry the oil to the main bearings, then through the drilled crankshaft to the crankpins, and through the tubes on the rods to the piston-pins. The overflow from the crankshaft and rod bearings forms a spray which lubricates the cylinders, cams and tappets. Oil pockets are provided on the camshaft bearings and idler and pump-



ONE OF THE LARGER SIZES OF THE SAME LINE OF ENGINE SHOWING THE GROUP ARRANGEMENT OF CYLINDERS

drive-shaft bearings. An oil feed to the gears is also provided at the front end of the oil header. The small helical gears on the rear end of the camshaft run in an oil pocket. Openings are cast leading into the valve spring chamber, so that the oil vapor can reach the valve stems.

A relief valve is fitted to the oil-pump, set to a pressure of 15 lb. per sq. in. The oil-pump is surrounded by a large

strainer, removable for cleaning purposes from the bottom of the engine, without disturbing other parts.

Provision is made for mounting electric starters and generators by the S. A. E. standard flange method. The generator is carried at the forward right side of the engine and the starters on the oil-pan just ahead of the bell housing, also on the right side. The distribution of the various accessories on these engines has been carefully worked out, so that ample room is provided to get at all units, and the valve-spring cover plates are also unobstructed.

On the test block this engine will develop 26 hp. at 600 r.p.m., 35 hp. at 800 r.p.m., 44 hp. at 1000 r.p.m., and 52 hp. at 1200 r.p.m.

This model can also be furnished with 5-in bore cylinders, in which case the power developed is about 10 per cent higher.

Two other sizes, a 4 by 6 in. and a 4¼ by 6 in., are also being built. These engines follow the foregoing specifications throughout with the exception that the cylinders are cast in block instead of in pairs, and the valve tappets are of the mushroom type. The various dimensions are, of course, reduced proportionately and the weight is about 660 lb.

For the smaller powers 3¾ by 5 in. and 4 by 5 in. sizes are being offered. With a few exceptions these engines follow the same general design. The weight of these models is about 525 lb.

The power developed by these latter units at 1000 r.p.m. is 33, 38, 23 and 27 hp. respectively.

PERSHING SQUARE, NEW YORK CITY

Gas Tractor Testing

By J. B. DAVIDSON[1] (*Member*)

TRACTOR MEETING PAPER *Illustrated with* PHOTOGRAPHS

IN the testing of gas tractors, as with any similar undertaking, it is best to determine clearly in advance the object to be attained. As analyzed, tests may be made for several distinct purposes, as follows:

(1) To determine the best adjustment of certain working parts, such as ignition, mechanism, valve timing, etc.

(2) To determine the distribution of the total heat obtained from the combustion of the fuel to useful work, to the cooling system, to radiation, etc.

(3) To determine the power output, first, of the engine in brake horsepower, and, second, of the tractor in drawbar horsepower.

(4) To determine the endurance of the tractor

This paper is planned to deal only with field testing, or the determination of the drawbar horsepower, the latter part of the third class of tests. Inasmuch as tractors are used more largely for traction purposes than for any other, it is obvious that the capacity of the tractor in drawbar horsepower is one of much importance. It is one important element of the value sold and purchased, and any test or procedure which will determine this element with accuracy is worthy of careful consideration.

STANDARD DRAWBAR HORSEPOWER RATING

The Society of Automotive Engineers has decided that as a matter of standard practice drawbar horsepower rating shall be based upon an actual test extending over 2 hr. on a firm traction surface. It is very clear that the present practice in rating followed by the tractor industry is anything but uniform, and must necessarily

A RECORDING DYNAMOMETER ATTACHED TO THE DRAWBAR AND READY FOR USE

be very confusing to the purchaser. The best evidence of this is furnished by the tests made at Salina during the 1918 National Power Farming Demonstration. These have not been made public, but in general show that for the forty-two tractors tested the drawbar horsepower delivered in actual tests varied from 50 to 200 per cent

A DYNAMOMETER OF THE INTEGRATING AND RECORDING TYPE ATTACHED TO A TRACTOR DRAWBAR

of their rating. Where such a condition exists the purchaser may be expected to be skeptical of tractor ratings in general.

The manufacturers of high-class tractors may be expected to welcome any development which will bring about uniformity of practice, since less sales effort will be needed to prove, disprove, and argue. To those who desire to overrate their product it is obvious that tests to prove capacity are very undesirable. If manufacturers are not able to bring about uniform methods of rating capacity, purchasers will sooner or later ask for it.

It may not be entirely out of place even in this short paper to discuss drawbar horsepower rating. Uniformity in practice is undoubtedly the most important consideration, yet a logical and practical basis for rating is worthy of careful study. This rating should represent a normal, full or average working power output under normal conditions. The 25 per cent reserve provided by the S. A. E. standard practice is not sufficient to care for the variations in field load, due to changing soil conditions or grades. In other words, it is seldom possible to give a tractor a load which will enable it to develop its rated drawbar horsepower continuously, because it does not have sufficient reserve to care for the ordinary or common variations in load. A large reserve would be desirable for two different reasons; first, there would be less trouble from overloading, one of the most fre-

[1]Professor of agricultural engineering, University of California, Davis, Cal.

quent causes of trouble; and second, the purchaser would not need to discount the rating in comparing a tractor with horse labor. In other words, it would be better either not to have any reserve or to have a sufficient amount to make the tractor comparable with horse labor.

With an increase in field and road speeds for tractors, for which there are some unanswerable arguments when conditions are favorable, the drawbar pull should be as much a part of the rating as the horsepower rating, for this pull determines the size and character of the implement drawn. The rated drawbar pull should be determined by a standard test and made a part of the tractor rating.

The proposal to do away with horsepower rating, and rate tractors in terms of the number of plows drawn, would leave us with the most haphazard system of all, for the reason that plows are not operated at a uniform depth, and the draft of a given size of plow, plowing at a uniform depth, will vary 200 per cent under different soil conditions.

It will be a comparatively easy task to educate the tractor purchaser to understand a tractor rating system, provided it is universally adopted, placed on a logical basis and faithfully carried out. In fact, there is now evidence of a demand from purchasers for such procedure.

Tractor Testing Instruments

In making a drawbar horsepower test there are two considerations of fundamental importance—accuracy and a clear, complete record of the conditions involved. The testing of tractors is too important a matter to permit of other methods than those which will give extremely accurate and reliable data. This is easier said than accomplished, because of the rapidly varying field conditions. A direct-reading dynamometer for determining the drawbar pull is practically worthless, on account of the wide and rapid fluctuations in draft due largely to the load but in part to the tractor. For this reason, a recording or integrating instrument must be used.

The Hyatt dynamometer is quite generally known and represents the recording type. A graphical record of the drawbar pull is obtained on a circular chart driven by a ground wheel. The record is made by a recording pressure-gage unit connected by a flexible tube containing liquid to a compression unit of the diaphragm type receiving the full drawbar pull. Minutes are recorded automatically on the record. The average drawbar pull is obtained by going over the record with a planimeter or other instrument.

The Iowa integrating and recording dynamometer receives the load either directly or through multiplying levers on a compression spring. The recording and integrating mechanism is operated by a thread attached to a fixed point while the test is being made. The test is made after the tractor is in operation and conditions become constant. The mechanism measures a fixed distance automatically and with great accuracy. A graphical record of the drawbar pull is recorded on a strip of paper which shows the variations in full and may be averaged by a planimeter. The instrument, however, is arranged to give a number proportional to the average drawbar pull for the measured run, by a recording wheel carried across the face of a friction disk. This average when the instrument is properly manipulated is extremely accurate. The instrument is especially useful in testing the draft of implements and was designed primarily for that purpose. Its design is based on the theory that a short accurate test, with all conditions constant and known, is more valuable than a longer one with many variations.

The argument has been advanced that it is undesirable to use a spring to receive and measure the drawbar pull. Attention is called to the fact that a spring, or the elasticity of suitable material, is the only practical means of measuring the force acting under the conditions, and it makes little difference whether it is used directly or indirectly.

The S. A. E. standard practice for drawbar horsepower rating calls for a continuous 2-hr. test. This is no doubt based upon the theory that 2 hr. is required to determine whether the tractor has sufficient endurance and that all parts will function continuously. However, no instrument has been designed to average or record the drawbar pull for this period. There are no difficulties, however, in arranging such an instrument, and if the 2-hr. period is to continue as the standard test such an instrument should be designed.

Again, it should be emphasized that much of the value of tractor testing depends upon the care with which the work is done, as when hastily performed it is of little or no value. Each test should be so carefully made and the conditions so accurately recorded that the results can be compared with other similarly conducted tests wherever they may be made. No small amount of tractor testing has been carried on in connection with tractor demonstrations. There are some advantages in having a number of tractors collected at one point where tests can be made under uniform conditions, but the hurry and excitement of a demonstration are serious disadvantages to overcome. If tests are to be made in connection with demonstrations, the management should give those in charge of them time to prepare and organize for their proper conduct. The competitive principle is undesirable because the final deductions or balancing may be in error. A better method is to make each test so that it can be easily compared with recognized standards of performance.

There would be greater interest taken in testing on the basis just proposed. It should be possible to arrange this through the cooperation of unattached and public service engineers. Without question it will make for the advancement of the tractor industry to establish definite records of performance.

The Discussion

CHAIRMAN E. A. JOHNSTON:—The standardization of tractor ratings is probably the most important subject before the industry today. Many states, in their legislatures and agricultural colleges, are agitating standardized rating to protect their citizens, and have some recognized means of comparing ratings that will apply to all makes of tractors.

PROF. E. A. WHITE:—I would like to call Professor Davidson's attention to the fact that there is a dynamometer on the market at the present time suitable for recording the drawbar pull of a tractor for a period of 2 hr. or longer. The Burr Co., Champaign, Ill., has for 15 or 20 yr. been perfecting and building railway dynamometers. It is recognized among mechanical engineers as the leading authority on dynamometer construction in the United States, if not in the world. It has already perfected a traction dynamometer suitable for recording time, distance, drawbar pull and total work for any test from 10 sec. up. There is absolutely no limit but the num-

ber of reels of paper you want to put on. It makes a horizontal record and gives evidence of being a machine for which the tractor industry has long been waiting. One of these machines was tried out by us last year in a series of plow tests which we have been conducting at the University of Illinois, and gave excellent satisfaction. The new tractor dynamometer, which is just now being put through has a drawbar capacity ranging from 1 to 10,000 lb. It is a machine built upon the hydrostatic principle, has a dynamometer unit and transfers the pressure to the recording apparatus through oil.

CHAIRMAN JOHNSTON:—The National Vehicle & Implement Association's Tractor Division, the American Society of Agricultural Engineers, and this Society, are all very much interested in this. We may talk for years about arriving at a fair standard, but unless we get together and actually take some action to decide the question the states will decide for us, and we shall have a different standard for every state, if we are not careful.

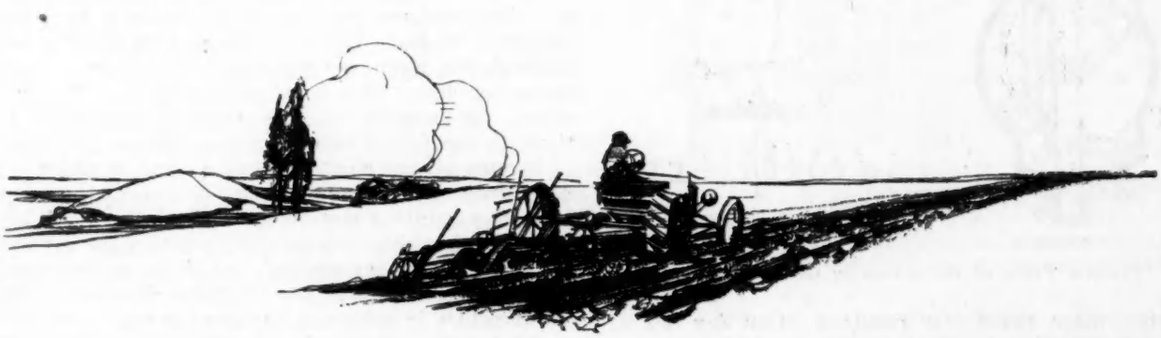
MR. DAVIDSON:—I recall that the Giddings recording traction dynamometer, an instrument now standard for many years, is now being made with 2-hr. and longer charts. In line with the suggestion of the last speaker, would it not be possible for the officers of the Society to take steps to form a coalition committee with the American Society of Agricultural Engineers and the National Implement & Vehicle Association's Tractor Section? Such a committee could be commissioned to proceed at once to prepare and recommend standard practice regulations for the testing and rating of tractors.

TRACTOR PRODUCTION IN 1919

ACCORDING to reports filed by tractor manufacturers with the office of Farm Equipment Control, Department of Agriculture, 132,697 tractors were built in 1918, and the production for 1919 is estimated at 314,936 tractors. The figures for 1919 are merely estimates and represent the aggregate of those submitted by tractor manufacturers in the first two months of the present year. The sales in the United States in 1918 were 96,470 tractors and the number on hand at the end of the year was 15,401, as compared with 15,525 on hand Dec. 31, 1917.

The number of tractors of various horsepowers built in 1918 and the estimated production for 1919 as compiled from the reports submitted by the different manufacturers are summarized in the accompanying table.

Makers' Rating Belt Horsepower	1918	1919
9, 10 and 12	1,141	8,220
16 and 18	20,629	48,545
20 and 22	72,238	157,671
24, 25 and 26	20,616	40,875
27, 28, 30 and 32	6,959	27,465
35 and 36	2,212	5,435
40 to 50	1,331	1,780
60 to 80	913	1,536
Not stated	6,658	23,409
Total	132,697	314 936

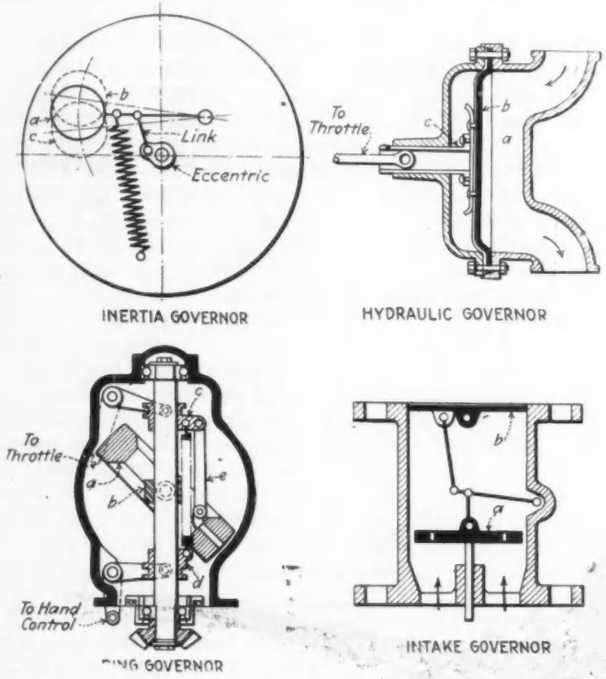


Governors for Truck and Tractor Engines

By R. B. Shoop[1] (*Member*)

Minneapolis Section Paper *Illustrated with* Drawings

THE function of a governor is to regulate engine speed between predetermined limits and to hold the speed to those limits during all the cycles of operation under all conditions, ranging from no load to full load. The history of governors is related very closely to that of the steam engine, and our present day instruments are largely adaptations or improvements of the steam engine type. James Watt discovered the necessity of some means to regulate the speed of this ponderous slow-moving engine and used the centrifugal type. Tradition informs us that the first governor was the result of a boy's desire to play. The old engines had a cord attached to the throttle-valve, and a boy was employed to watch the speed of the engine and pull the



Various Types of Governors in General Use

cord when more steam was required. One day one of these boys yielded to his desire to play and tied two apples to the cord. The scheme worked, and the present-day governor was born, some of the present governors closely resembling that two-apple governor in action.

The governing of an engine can be divided into three classes:

(1) Hit-or-miss
(2) Throttling
(3) Variation of ignition point

[1]Mechanical engineer, McVicker Engineering Co., Minneapolis, Minn.

The third class is in practice largely a manual operation, except where mechanical means are provided in the magneto to vary the time of the explosion; this can be omitted from our discussion. The hit-or-miss type is now obsolete in the truck and modern tractor. In this type the governor acted on a pawl of "pick blade," which in turn held the exhaust-valve open or the fuel valve closed, allowing a charge of pure air to enter the cylinder instead of a charge of gas. The throttling governor is now universally used, as modern design has improved the economy of this type to such an extent that the better regulation more than offsets the possible saving in fuel and does away with the trappy devices and irregular explosions of the hit-or-miss governor.

In both the hit-or miss and throttling types of mechanical governor we may have one of three classes or a combination of two:

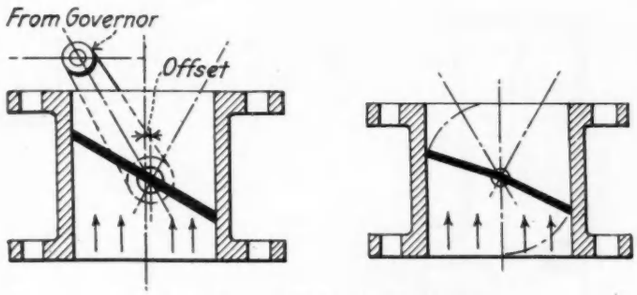
(1) Centrifugal
(2) Inertia
(3) Pendulum

The first two will be treated later. The pendulum governor is described by its name and is used largely on the hit-or-miss type.

The Electric Governor

The past year has brought to us a new type, which we are all watching with deep interest, the electric governor. This device combines the governor, ignition, lighting and starting generator, coil and box, distributor and controller. The direct-current generator is a four-pole shunt-wound type. The housing is mounted on trunnion bearings, which allow the generator to turn through an arc of 30 deg. The trunnion bearing shaft is brought through the generator housing, and a lever is placed on the outer end. This lever is connected to the throttle-valve. A portion of the current generated passes through the field windings, which causes the iron cores to become strong electro-magnets, thus creating a magnetic drag on the armature, and the revolving armature imparts a rotating motion to the field frame. When the controller is placed in any given position the corresponding speed will be maintained, for if the engine speeds up due to decrease in load, the magnetic drag of the field of the armature is increased, causing the field frame to turn in the direction of armature rotation and close the throttle. If the load is increased the magnetic drag is decreased, allowing the field frame to be turned by a spring, to which is attached a piston operating in a dashpot to prevent too rapid movement of the arm controlling the throttle-valve. A hand-wheel on the control box indicates the speed at which the governor holds the engine. The speed range is from 400 to 1650 r.p.m., but the manufacturer will supply proper speed ratio to hold the engine at any required rate. A starting motor can be used with this device.

There are a number of variable factors entering into the design of a governor: The work the engine is required to perform, the allowable variation between no load and full load, size and type of intake control valve, flywheel inertia, speed, the manufacturing facilities and inspection, and, unfortunately, the compromise sometimes necessary due to lack of space. If an engine is to do such work as threshing and plowing, where there is a sharp rise in the power curve, the weights, springs, rise of governor collar, etc., should be greater than on light work. The weights should be balanced and the



Two Types of Governor Valves

springs calibrated so that there will be no binding or unequal pressure of moving parts. All moving parts should be enclosed in an oil-tight dust-proof case and run in an oil bath or vapor. Ball bearings should be used on the principal parts and especially on thrust bearings. Some manufacturers even mount the throttle-valve on ball bearings.

The main fault of governors, aside from not being able to see the approaching hill or the extra bundles thrown into the separator, is hunting. This is due to the fact that where there is a change in load, the governor makes an effort to take care of it. As there is friction of parts, the energy required to start the parts moving is greater than that needed to keep them in motion; so the throttle overruns its position. This speeds or retards the engine, and the reverse action is necessary to maintain an equilibrium. Larger weights with proper springs, proper fittings, balanced throttle-valve and anti-friction bearings will all help to overcome this defect.

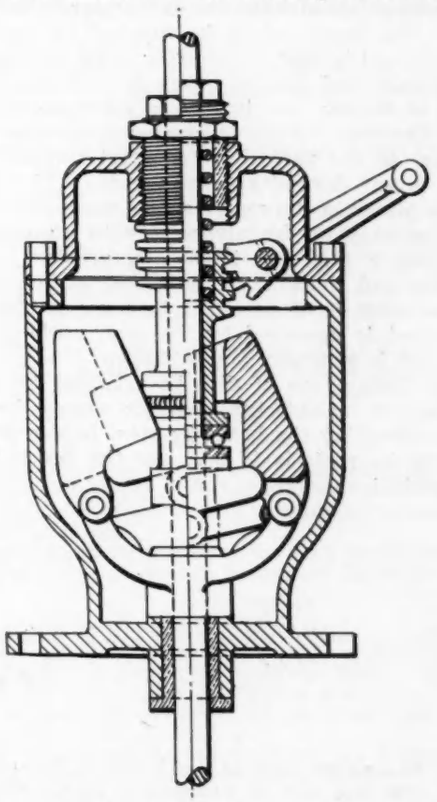
The best way to mount a governor valve when separated from the governor proper is in a cage. This allows a proper correlation of parts without depending on the carbureter and also allows a change in the carbureter without disturbing the governor parts. The governor should be set to run the engine at maximum speed with the carbureter valve open. The retarding should be done with the carbureter control valve or governor speed controlling device. It is unfortunate that corporal punishment has been revoked in most states, as this should be the penalty for the man who tinkers with the governor.

The Different Kinds of Governors

In a centrifugal governor, the so-called Watt or fly-ball type, we have two or more weights revolving about the center spindle and connected to a sliding sleeve, which is in turn connected to the throttle-valve by a bell-crank or lever. The proper resistance to the centrifugal force of the balls is maintained by a loaded sleeve or by springs. The loaded sleeve may be weighted by metal or actuated by a single spring mounted on the spindle or by double springs attached directly to the weights.

One of the types, the inertia governor, is seldom if ever used on trucks and tractors, due to the difficulty of mounting it properly in the limited space allowed for the governor and in balancing the revolving parts. In a governor of this type the scope of action is a plane perpendicular to the axis of the shaft, and the inertia of the weight *a* will make the governor more prompt in its action. If the governor is moving in the direction shown by the arrow and the load is removed, the engine speeds up. The inertia of the weights will hold it back and it will move to position *b*. If the load is suddenly applied, the inertia of *a* will cause it to surge forward to position *c*. This type of governor does not have the hunting tendency of the purely centrifugal type.

The ring governor was developed by one of the automobile companies and is an adaptation from marine steam engine practice. This is a centrifugal governor in which the balls are replaced by a metal ring *a* pivoted to the collar *b*, which is mounted on and driven by the spindle. The ring *a* is connected to the sliding collar *c* which actuates the bell-crank connected to the throttle by the link *e*. There is a lower sliding collar *d* to which



A Recently Developed Tractor Governor Employing a Circular Rack and Pinion in Place of the Sliding Sleeve

is attached the hand control linkage. This is attached to the upper collar *c* by a spring. This gives both automatic and manual control and is one form of speed regulator.

The hydraulic governor has been successfully used on at least one popular line of trucks. The device is interposed between the pump and the engine. It consists of a water chamber *a*, with the diaphragm *b* connected to the plunger *c* which is attached to throttle linkage. There is a speed and pressure constant for each engine speed, and the diaphragm assumes the proper position for each, thus regulating the throttle-valve.

An intake governor, or a governor operated by the speed of incoming gases, is another form. The floating disk or piston *a*, which is calibrated for a velocity and butterfly friction by side clearance and vertical holes, moves up and down according to air speed and operates the butterfly *b* through the series of links. The moving parts are made of aluminum for lightness. This governor is interposed between the carbureter and the intake manifold.

Among other types of governor are the transmission governor, which regulates the engine speed from the top shaft of the transmission, and the road wheel governor, which is driven from the front wheel by a flexible shaft the same as a speedometer.

Governor Valves

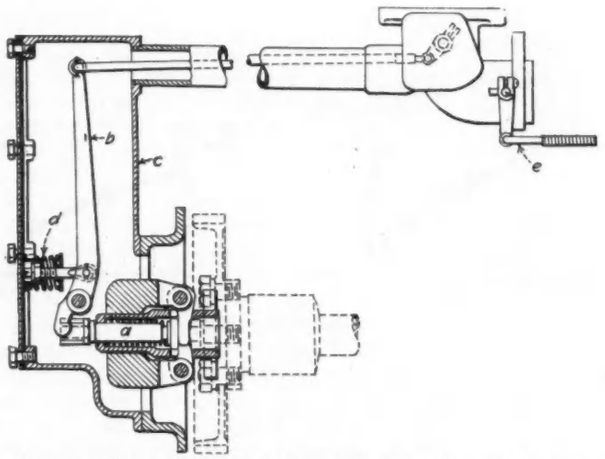
An investigation of governors is not complete without study of their valves. The governor may be attached to the butterfly valve of the carbureter, but a separate valve-cage is much better. This allows governor action unhampered by the extra linkage of the manual control. The governor should be set with the engine operating at maximum speed when the carbureter butterfly is wide open. The hand control is attached to the carbureter butterfly and is used for slowing down the engine.

A widely used type of governor valve has the butterfly set at 60 deg., but it may be set at 90 deg. with the axis. The working arc is greater with more chance for hunting, as the valve has to travel farther from full-closed to any desired area of opening. If the butterfly stem is placed in the center of the valve, the pressure of incoming gases on the advancing side is greater than on the opposite side and imposes a greater load on the governor and linkage. This makes for uneven action, and the stem is often offset to equalize this pressure. This offset is governed by the size, angle and gas velocity, but is generally about 1/32 in.

A particular type of disk brought out by one of the large engine manufacturers which serves the same object as offsetting the butterfly stem is also shown. The angle on the right is 17 deg. and the left is 25 deg. on this particular design.

There are other types, such as piston-valve, gate-valve, plates, grids, etc. The piston-valve can be balanced, but the other types impose more or less extra load on the governor due to the force of the incoming gases. The butterfly valve seems to have the lead, as it is serviceable and easily manufactured and installed.

One of the most recent tractor governor designs is a very compact, efficient governor equipped with a simple speed-changing device and a spindle spring instead of the double springs frequently used. The governor works



Another Recent Tractor Governor Having Manual Control

through a circular rack and pinion instead of the typical sliding collar.

In the complete governor and governor valve installation used by one of the largest tractor manumacturers, the weight yoke is bolted directly to the camshaft and the weights operate the spindle *a* which actuates the governor arm *b*. The casing *c* is bolted to the engine housing, and all parts are lubricated from the crankcase. The speed-changing device is shown at *d*. The manual control is shown at *e* and is spring-mounted.

OBITUARIES

S. L. Blackburn died at his home in Rock Hill, S. C., Feb. 27. He was born at Vaughndale, N. C., May 22, 1882, and attended the students' course of the Stanley Electrical Mfg. Co., Pittsburgh, Mass., from 1900 to 1902. From 1903 to 1909 he was in the sales department of the Tower-Binford Electric Mfg. Co., Richmond, Va. In 1910 Mr. Blackburn went with the Westinghouse Electric & Mfg. Co., as a division manager, and in 1913 was appointed district manager of the automobile engineering division of that company, with headquarters at Cleveland, Ohio. At the time of his death he was vice-president and director of sales and advertising for the Anderson Motor Co., Rock Hill, S. C., a position which he had held since 1917. Mr. Blackburn was elected a Member of the Society on Jan. 8, 1915.

Samuel B. Dusinberre died at his home in Detroit, Mich., on March 26, aged 54 years. At the time of his death Mr. Dusinberre was Western sales manager of the New Departure Mfg. Co., with headquarters at Detroit, a position which he had held since 1911. From 1906 to 1908 he was general manager of the Westinghouse Storage Battery Co. at Bayonne, N. J. Previous to that he was purchasing agent for the Westinghouse Machine Co., Pittsburgh. When the storage battery plant was destroyed by fire in 1908 he became assistant general manager at the Alden Sampson Mfg. Co. He is survived by his widow. Mr. Dusinberre was elected to the Associate Member grade of the Society, July 26, 1911.

John Edgar Johnson, secretary and treasurer of the Warner Gear Co., Muncie, Ind., died on March 30. He was born at Ashtabula, Ohio, Aug. 16, 1873, and was elected an Associate Member of the Society on May 14, 1917.

John O. Palmer, a senior in the mechanical engineering course at Stevens Institute of Technology, died Jan. 30. He was born at Newark, N. J., on Sept. 27, 1897, and had been an enrolled student of the Society since March 25, 1918.

Current Standardization Program

AT the Annual Meeting of the Society held Feb. 5, thirty-one recommendations of the various Divisions of the Standards Committee were approved for final presentation to the voting members of the Society. These were adopted in their entirety by the letter ballot, which closed on April 5. The reports on which this action was taken were printed in THE JOURNAL in the March issue, on pages 150 to 158 inclusive.

Result of the Letter Ballot

The complete vote on the recommendations is given below.

	Yes	No	Not Voting	Blank
REPORT OF BALL AND ROLLER BEARINGS DIVISION				
Annular Ball Bearings, Separable (Open) Type	152	1	59	14
Annular Ball Bearings, Extra Small Series	145	1	66	14
Angular Contact Ball Bearings—Light, Medium and Heavy Series	150	1	60	15
REPORT OF CHAIN DIVISION				
Roller Chain Nomenclature	128	1	78	19
REPORT OF ELECTRICAL EQUIPMENT DIVISION				
Sleeve-Type Starting-Motor Mounting	139	8	67	12
Non-Magnetic Magneto Shims	145	1	67	13
Magneto Couplings—Flexible Disk	154	2	58	12
REPORT OF ENGINE DIVISION				
Engine Support Arms—Truck	111	9	85	21
REPORT OF MISCELLANEOUS DIVISION				
Nuts for Machine Screws	147	4	56	19
Spark-Plug Dimensions — Aeronautic	116	0	94	16
REPORT OF SPRINGS DIVISION				
Leaf Points—Nomenclature	131	0	74	21
Leaf Points	128	0	77	21
Test for Parallelism	123	5	78	20
Eye Bushings and Bolt Tolerances	120	4	81	21
Wrapped Eyes	123	3	80	20
Width of Spring Ends	125	3	78	20
Rebound Clips, Spacers and Bolts	122	2	81	21
Spring Widths and Lengths, Eye and Clip Diameters for Commercial Vehicles	114	2	89	21
Spring Widths and Lengths, Eye and Clip Diameters for Passenger Cars	115	5	86	20
Frame Brackets	118	5	82	21
Leaf Spring Specifications	127	2	77	20
Finish of Springs	129	1	77	19
REPORT OF TIRE AND RIM DIVISION				
Industrial Truck Tires	108	2	101	15
Base Bands for Solid Tires	105	8	98	15
Base Bands for Industrial Truck Wheels	97	7	107	15
Solid Tire Sections	111	2	99	14
Wood Felloe Dimensions—Pneumatic Tire Rims	128	1	84	13
Allowable Tolerances for Felloe Bands	124	0	89	13
Edges of Felloe Bands	125	0	88	13
Pneumatic Tires for Motorcycles	98	8	107	13
Valve-Hole Size, Automobile Rims	124	4	85	13

Regulations Governing Work

At the meeting of the Council held on April 12, the rules governing the work of the Standards Committee were revised. The regulations in the amended form are given below.

ORIGIN

The Standards Committee of the Society of Automotive Engineers may be composed of members or non-members of the Society.

FUNCTIONS

The Standards Committee under the discretion of the Council shall have jurisdiction over the formulation of all Standards and Recommended Practices which may come before the Society for final adoption.

It may also be charged with such special deliberations or investigations, as the Council may deem advisable or necessary for the preparation of authoritative reports.

The results of these investigations may, in the discretion of the Council, be made the subject of special reports.

ORGANIZATION

The Standards Committee shall act under the direction of a Chairman, who shall be, ex-officio, a member of each Division, and shall be assisted by a Standards Manager.

The whole Committee shall be resolved by the Council into a number of Divisions, each charged with the consideration of a group of subjects, and presided over by a Division Chairman.

Any Division may be resolved further into such Subdivisions as the Division Chairman may deem expedient.

APPOINTMENTS

Appointments to membership on the Standards Committee shall be made annually by the Council in conference with the Chairman of the Standards Committee.

Interim appointments may be made by the Council.

The Chairman of the Standards Committee and of its Divisions shall be designated annually by the President of the Society.

The President and the Secretary of the Society shall be, ex-officio, members of the Standards Committee and of its Divisions.

PERSONNEL

Sub-Divisions

The Chairman of Sub-Divisions shall be appointed by the respective Division Chairman.

Sub-Division members may be members or non-members of the Society.

Appointments on Sub-Divisions shall be subject to the approval of the Standards Committee Chairman.

Divisions

Conferees of Divisions shall include all appointees who are not members of the Society. A conferee shall upon qualifying as a member of the Society become a member of the Division. Conferees shall have no vote, but may serve in an advisory capacity and participate in discussions at all meetings.

One or more representatives of any one company may be appointed to Divisions or Sub-Divisions.

PROCEDURE

In Sub-Division

Reports on proposed new standards or revision of existing standards, may issue from a Sub-Division as preliminary reports only, and shall be submitted to the respective Division for approval.

In Division

Sub-Division reports may be amended or referred back to Sub-Division by the Division.

However initiated, a proposed new standard or revision of an existing standard must issue as a report from that particular Division within whose province such matters properly belong, under assignment by the Council of the Society.

No action affecting the substance of a report shall be taken by any Division except at a meeting called

for that purpose or, at the discretion of the Standards Committee Chairman, by letter ballot of the Division. Approval of a report by letter ballot shall be by majority of the voting members of the Division. Voting by proxy is not permissible.

Reports shall consist generally of complete but concise statements of the practices and constructions, as recommended, together with such illustrations as may be necessary. There should be appended also explanatory remarks of the recommendations made.

A majority of voting members of a Division shall constitute a quorum thereof.

In the case of more than one member of the Division being associated with a given company, only one vote shall be cast on behalf of such members in Division meetings.

Dissenting members have the right to present minority reports individually or jointly.

All Division actions in meetings of the Division not approved by the vote of all the members of the Division shall be submitted by letter ballot to all the voting members of the Division.

In Standards Committee

Reports of the Divisions shall be submitted to the Standards Committee for approval at regular or special sessions.

Upon approval by the Standards Committee in original or amended form, Division reports shall be transmitted, with a statement of the action thereon, to the Council for approval in original or amended form for submission to the Society.

Fifteen members of the Standards Committee shall constitute a quorum.

The majority of those voting in a Standards Committee meeting shall be necessary to approve a report. Voting by proxy is not permissible.

In Society Meeting

Division reports, when approved by the Council, shall be submitted to the Society for discussion at a duly called regular or special meeting.

Division reports may be amended or referred back with instructions.

A majority of the votes cast at a Society meeting is necessary to approve reports for submission by letter ballot to the members of the Society.

The Letter Ballot

Before adoption Division reports approved at a Society meeting shall be submitted by letter ballot to the voting members of the Society.

The letter ballot shall provide for the recording of affirmative and negative votes and waivers.

The letter ballot shall be returnable to the Secretary of the Society within 60 days following the Society meeting.

The letter ballots shall be opened and recorded by three tellers appointed by the president of the Society.

The adoption of a report shall be determined by the majority of the letter ballots cast. Voting by proxy is not permissible.

MEETINGS

Committee Meetings

Meetings of the Standards Committee shall be held on the first day of or on the day preceding each Annual and each Semi-Annual meeting of the Society. Special meetings may be held by direction of the Council.

Division Meetings

A meeting of a Division may, with the approval of the Standards Manager and the Secretary of the Society, be called on 10 days' notice, at the suggestion of the respective Division Chairman, or may be called on 10 days' notice by direction of the Secretary of the Society.

COMMITTEE RECORDS

Attendance

The Standards Manager or other representative of the Standards Department of the Society shall record the minutes, including the names of those in attendance, of Division meetings. In the absence of such representative, a suitable record of the proceedings of a meeting of a Division, or of members thereof, shall be made by or by direction of the Chairman or Chairman pro tem of the meeting.

Depository for Records

The Chairman of any Division, or member thereof, shall after completion of work on any subject referred to the Division, transmit to the office of the Standards Committee any papers or correspondence relating thereto he may have in his possession.

MISCELLANEOUS

Publicity

A Division or a member thereof shall not have the right to issue matter for publication through other than the regular Society channels, unless so authorized for reasons of weight by the Council.

Stationery

Official correspondence, especially requests for information as to practice, should be conducted on official stationery, which will be furnished by the Secretary of the Society as necessary to Chairmen and members of Divisions for use in conduct of special work.

Expenditures

No obligation for expenditures other than postage will be assumed by the Society unless such expenditure shall have been incurred in pursuance of previous authorization by the Council, and then only within specific fixed amounts.

Assignment of Subjects

The subjects assigned to the various Divisions of the 1919 Standards Committee and the scheduled meetings of the Divisions are given below.

AERONAUTIC DIVISION

Aeronautic Steel Tubing, Clip Ends, Eye Bolts, Fabric Test Specification, Fittings for Air Pipe Lines, Fittings for Fuel Pipe Lines, Fittings for Lubricant Pipe Lines, Gas Tank Blow-Off Valve Connections, Glue Test Specification, Hand Air-Pump Connections, Heat Treatment of Frame Joints, Lock Washers, Loops for Flexible Multiple-Strand Steel Cable, Loops for Non-Flexible Single-Strand Steel Cable, Marking Electric Wiring, Marking Spark and Throttle Levers, Methods of Chemical Analysis; Methods of Mechanical Tests, (a) Heat Treatment, (b) Brinell Test; Plain Washers, Pontoon Hand-Pump Connections, Propeller-Hub Lock Fittings, Propeller-Hubs, Propeller-Hub Rating, Propeller Shaft-End, Protective Coatings for Metal, Radiator Hose Specification, Rod-End Pins—Aeronautic, Round High-Strength Steel Wire (Revision), Shackles, Sheaves for Control Pulleys, Spark-Plug Dimensions, Streamline Wire, Streamline Wire Ends, Swedged Wire and Ends, Tires—Landing Wheel, Turnbuckle Safety Wires and Wiring, Twin Carbureter Flanges and Wood—Tests and Specifications.

Meetings of the Division are scheduled for May 8 and June 5 at New York City.

BALL AND ROLLER BEARINGS DIVISION

Airplane Ball Bearings; Annular Ball Bearings, Extra Large Type, Extra Light Series; Annular Ball Bearings, Extra Large Type, Light Series; Annular Ball Bearings, Extra Large Type, Medium Series; Roller Bearings (Taper and Straight), Thrust Ball Bearings, Metric Sizes and Corner Radii Tolerances.

A meeting of the Division is scheduled for May 20 at New York City.

CHAIN DIVISION

Roller Chain Lengths and Sprocket Tolerances, Roller Chains—Heavy Series and Roller Chains—Light Series.

ELECTRICAL EQUIPMENT DIVISION

Cable Terminals for Ignition Distributors, Generators, Meters and Switches; Electrical Apparatus (a) Supply and (b) Distribution; Electrical Instrument Mounting Dimen-

sions, Magneto Dimensions—Aeronautic, Protectors for Cable Terminals, Ratings of Storage Batteries (Farm Lighting Equipment), Specifications for Insulated Wire and Charging Cables and Voltage Test for Insulated Wire.

Meetings of the Division will be held at Detroit on May 6 and 29.

ENGINE DIVISION

Engine Performance Data, Engine Performance Tests, Kerosene Engine Testing Forms and Tire Pump Mounting—Engine.

A meeting of the Division will be held at Detroit on May 28.

IRON AND STEEL DIVISION

Aeronautic Screw Stock, Aeronautic Sheet Steel, Aeronautic Steel Alloys, Aeronautic Steel Bars, Aeronautic Steel Specification, Cast-Iron Specifications for Valve-Heads, Chromium Steels, Finish of Sheet Steel, Heat-Treated Steel Castings, Limits for Cold-Rolled Bar Stock, Malleable Iron Specifications, Nickel Steel Specification, Review of Steel Screw-Stock Specification, Standard Classes of Sheet Steel, Steel Casting Specification, Spring Steel Specification, Temper of Sheet Steel, Tungsten Steel Specification, Steel Magnification and Tolerance on Bars.

A meeting of the Division will be held at New York City on May 15.

LIGHTING DIVISION

Bases and Sockets—Electric Bulbs, Focusing Length of Incandescent Lamps, Headlamp Brackets, Headlamp Illumination and Lens Sizes.

A meeting of the Division will be held at New York City on May 22.

MISCELLANEOUS DIVISION

Ball-and-Socket Joints, Brake-Shaft Bushings, Connecting-Rod Bolts, Exhaust Heater Connecting Flange, Finish of Nut Faces, Flexible Tubing, Fuel Tank Caps, Horn-Mountings, Hub Odometers—Truck, Radiator Caps, Screw and Bolt Classification, Speedometer Mounting, Steering-Wheel Hubs, Tap Drill Size List, Thread Tolerances and Tire-Valve Dimensions.

Meetings of the Division will be held at Detroit on May 7 and May 26.

MOTORCYCLE DIVISION

No subjects have been assigned to this Division, but it is expected that the Standards and Recommended Practices for the military motorcycle will receive consideration.

A meeting will be held at Chicago on June 2.

NON-FERROUS METALS DIVISION

Aluminum Alloy Specification, Brass Specification (Cast, Drawn), Bronze Bearing Metals, Bronze Specification (Cast, Drawn), Lead Base Alloys, Non-Ferrous Metals Research and Zinc Base Alloys.

SHAFT FITTINGS DIVISION

Review of Shaft-End, and Review of Spline Fittings.

A meeting of the Division will be held at New York City on May 29.

SPRINGS DIVISION

Brinell Transverse Bend Test, Length of Spring Seats, Methods of Greasing and Oiling Spring-Bolts, Spring-Bolts for Commercial Vehicles, Spring-Bolts for Passenger Cars, Spring Clips, Spring-Pins for Commercial Vehicles, Test of Commercial Spring Steel and Trailer Springs.

Meetings of the Division will be held at Detroit on May 7 and on May 31 at either New York City or Philadelphia.

STATIONARY ENGINE AND LIGHTING PLANT DIVISION

Adaptability of S. A. E. Engine Testing Forms, Approval of Existing S. A. E. Standards and Recommended Practices, Crankshaft Diameters and Pulley Extensions, Cylinder Lubricators and Grease-Cups, Flanges for Cast-Iron Carbureters, National Gas Engine Association Standards, Pipe Flanges (Oval and Round), Portable Truck Engine Mountings; Screws, Studs, Nuts and Lock Washers; Simplified Series of Stationary Engine Sizes, Valves and Valve Collars and Voltage and Capacity Rating of Farm Lighting Outfits.

A meeting of the Division will be held at Chicago on June 1.

TIRE AND RIM DIVISION

Airplane Landing Wheels, Carrying Capacity of Solid Tires, Pneumatic Tire Sections, Pneumatic Tires for Passenger Cars and Commercial Vehicles, Rim Dimensions—Cast Steel Wheels, Rubber Tires for Tractors, S. A. E. Deflection and Set Tests for Rims, Section Dimensions of Solid Tire Single and Dual Wheels with reference to thickness of permanent metal felloe band; Solid Tire and Wheel Diameters, Wheel Circumferences; Solid Tire Sizes and Wood Spokes, Passenger Cars.

TRACTOR DIVISION

Approval of Existing Standards for Tractors, Fuel and Lubrication Pipe Lines, Height of Tractor Drawbar, Punching of Driving-Wheels, Spark-Plug Dimensions, Tractor Belt-Speed, Tractor Flywheel Housings and Tractor and Implement Drawbar Connections.

Meetings of the Division will be held at Chicago on May 9 and 31.

TRANSMISSION DIVISION

Disk Clutch Dimensions, Gear Shifter Forks and Grooves, Gear Standardization, Power Take-Off on Trucks, Tire Pump Transmission Mounting, Transmission Bearing Caps, Transmission Drive for Speedometers, Transmission Rear Bearing and Oil Retainer and Universal Joint Dimensions.

A meeting of the Division will be held at Detroit on May 13.

TRUCK STANDARDS DIVISION

Drive Connections for Loading and Unloading Devices, Frame Widths and Trailer Hitches.

A meeting of the Division was held at New York City on April 21 to formulate a program of further work. A conference was held with the committee of the National Automobile Chamber of Commerce appointed to cooperate with the Society on truck standardization matters. The next meeting of the Division will be held at Detroit on May 27.

Iron and Steel Division Meeting

A meeting of the Iron and Steel Division was held at New York City on April 10, at which a number of subjects were discussed.

S. A. E. STEEL SPECIFICATION NUMBERS

General discussion indicated that the use of a prefix letter or symbols other than a simple number for designating steel specifications, such as "X" in "X3315," is undesirable, as it frequently leads to confusion and misinterpretation. The effect of changing specification numbers in drafting-room and other records throughout the industry was also considered.

When the present system was adopted it was the intention that the second figure of the specification number should represent the approximate percentage of the alloying element, but in view of the fact that this interpretation of the specification number is not generally known, and in view of the increase in the number of alloy steels rendering a continuation of this system difficult, the Division deemed it feasible to eliminate prefix letters altogether and it was voted that the use of any method of designating specifications except by straight numerical series is objectionable.

REVIEW OF STEEL SCREW-STOCK SPECIFICATION

Chairman Gilligan reviewed the early action taken by the Iron and Steel Division with the American Society for Testing Materials toward a revision of the present S. A. E. screw-stock specification and adopting the latter's revised specifica-

tion. In the discussion it was stated that most of this steel is made to that specification, notwithstanding the S. A. E. limits. It was voted to recommend for adoption the American Society for Testing Materials chemical compositions for both Bessemer and open-hearth screw stock with the specification numbers given below. These steels are intended for general automatic screw machine products not requiring more particular properties.

Specification No. 1112—*Bessemer Screw Stock*

Carbon	0.080 to 0.160 per cent
Manganese	0.600 to 0.800 per cent
Phosphorus	0.090 to 0.130 per cent
Sulphur	0.075 to 0.150 per cent

Specification No. 1120—*Open-Hearth Screw Stock*

Carbon	0.150 to 0.250 per cent
Manganese	0.600 to 0.900 per cent
Phosphorus, not to exceed	0.060 per cent
Sulphur	0.075 to 0.150 per cent

The desirability of providing a free machining stock that will possess better physical properties than afforded by the two types of screw stock under specifications No. 1112 and 1120 was discussed. A steel possessing such properties is desirable for parts which must be made with automatic screw machines, and which in addition to being free cutting, should be more resistant to shock than the common types of screw stock.

It was voted to recommend for adoption a new type of open-hearth stock for preferred use to be known as "Open Hearth Free-Machining Stock," designated as specification No. 1100, with chemical composition as follows:

Specification No. 1100—*Open-Hearth Free-Machining Stock*

Carbon	0.15 to 0.25 per cent
Manganese	0.60 to 0.90 per cent
Phosphorus, not to exceed	0.06 per cent
Sulphur	0.06 to 0.09 per cent

The "Notes and Instructions" of the Iron and Steel Division Report will then include the following note under Specification No. 1100:

> This steel is intended for miscellaneous parts where greater toughness is desired than is afforded by specifications No. 1112 and 1120, and where better machining properties are desired than is afforded by specification No. 1020.

STEEL CASTINGS

The present S. A. E. steel casting specification conforms with the 1916 specifications of the American Society for Testing Materials for Class B, annealed, steel castings. At the Winter Meeting the Division recommended the adoption of the 1918 specifications for the same type of castings. The latter specification, however, contains a so-called war clause permitting 0.06 per cent sulphur in all types of castings and 0.06 per cent phosphorus in acid steels "for the period of the war or until otherwise ordered by the Society." (American Society for Testing Materials) The S. A. E. Standards Committee took unfavorable action upon this report and returned the specification to the Division for reconsideration.

In view of the fact that the American Society for Testing Materials was to discuss the disposition of this war clause April 11, it was decided that the subject of steel castings should be tabled until it was ascertained what action that organization would take.

The suggestion was made that if automobile manufacturers consider it advisable to have closer chemical requirement for steel castings, a note could be appended to the S. A. E. specification, or a new specification could be prepared calling for phosphorus and sulphur not to exceed 0.035 per cent, thereby demanding an electric furnace product.

In connection with any future specification for steel castings, it was voted that the following note should appear under such specification and in the "Notes and Instructions":

> All steel castings shall be properly annealed, the treatment depending upon the design and chemical composition of the castings.

NICKEL-CHROMIUM STEELS

The question of revising the nickel and chromium limits on series 3100 and 3200 was discussed. The adoption of the nickel and chromium limits used in Signal Corps specification No. 10023-C, namely, 1.25 to 1.75 per cent nickel, and 0.60 to 0.90 per cent chromium, in specifications No. 3120, 3125, 3130, 3135 and 3140 was advocated as well as nickel limits of 1.75 to 2.25 per cent and chromium limits of 0.80 to 1.10 per cent in connection with specifications No. 3220, 3230 and 3240.

After considerable discussion, it was voted to retain the present limits until a request for changes is submitted, supported by specific data as to the physical requirements desired and particular changes in elements recommended.

In accordance with the vote taken early in the meeting, the following specification numbers containing letters were changed, as follows:

X3315 to 3415
X3335 to 3435
X3350 to 3450

CHROMIUM STEELS

It was voted to eliminate specifications No. 5195, 51120 and 52120 as not being required. It was voted to change the chromium range in specifications No. 5120, 5140 and 5165 to read 0.60 to 0.90 per cent (0.75 desired) in place of the present ranges of 0.65 to 0.85 per cent (0.75 desired). The reason advanced for this was that the bulk of the trade is willing to accept chromium within this range and it affords the mills additional leeway in their mixes.

It was voted to change the present specification No. 5295 to No. 52100 and to change the carbon, manganese and chromium limits of this specification. As thus revised, specification No. 52100 (suitable for steel for ball bearing races) will read:

Carbon	0.95 to 1.10 per cent (1.00 desired)
Manganese	0.20 to 0.50 per cent (0.35 desired)
Phosphorus not to exceed	0.03 per cent
Sulphur not to exceed	0.03 per cent
Chromium	1.20 to 1.50 per cent (1.35 desired)

It was voted to add a specification for high-chromium steel, otherwise known as "Stainless Steel," to cover the type of steel now used to a large extent for the exhaust valves of aircraft and automobile engines. This specification will be known as No. 51230.

Specification No. 51230

Carbon	0.200 to 0.400 per cent (0.300 desired)
Manganese not to exceed	0.500 per cent
Phosphorus not to exceed	0.035 per cent
Sulphur not to exceed	0.035 per cent
Nickel not to exceed	0.500 per cent
Chromium	11.500 to 14.000 per cent

TUNGSTEN STEELS

The need of specifications for high-tungsten steels for exhaust valves was brought up, and it was the general opinion that tungsten steels similar to types W60 and W60A of United States Signal Corps specification No. 10023-C comply with general practice. It was voted that the S. A. E. steel specifications should include two types of high-tungsten steel to be known as specifications No. 7060 (Signal Corps No. W60) and No. 7160 (Signal Corps No. W60A):

Specification No. 7060

Carbon	0.500 to 0.700 per cent (0.600 desired)
Manganese not to exceed	0.300 per cent
Phosphorus not to exceed	0.035 per cent
Sulphur not to exceed	0.035 per cent
Chromium	3.000 to 4.000 per cent
Tungsten	13.000 to 15.000 per cent

Specification No. 7160

Carbon	0.500 to 0.700	per cent (0.600 desired)
Manganese not to exceed	0.300	per cent
Phosphorus not to exceed	0.035	per cent
Sulphur not to exceed	0.035	per cent
Chromium	3.000 to 4.000	per cent
Tungsten	16.000 to 18.000	per cent

SULPHUR AND PHOSPHORUS LIMITS

Attention was called to the fact that owing to the raw materials now available for the mills to work, which contain a large amount of returned scrap carrying high phosphorus and sulphur content due to war conditions, it is necessary for steel users to consider widening the permissible limits for phosphorus and sulphur in the plain carbon and simple alloy steels. After extended discussion it developed that some users preferred to adhere to the present limits but other large users were inclined to favor increasing the present sulphur limits on simple alloy steels by 0.005 per cent. They were not anxious to increase the present carbon steel limits beyond 0.05 per cent or to increase the sulphur limits on medium and high chrome-nickel, chromium-vanadium and other high-alloy steels beyond the present limits of 0.04 and 0.03 per cent respectively. It was the opinion of all the members that the phosphorus limits should not be raised for any types of steel.

Tire and Rim Division Personnel

The members of this Division and their assignments to the different Sub-Divisions are as follows:

Charles B. Whittelsey, *Chairman*

PNEUMATIC TIRES FOR PASSENGER CARS

W. H. Allen	E. C. Hulse
C. I. Bradley	William McMahon
Burgess Darrow	J. C. Tuttle

PNEUMATIC TIRES FOR COMMERCIAL VEHICLES

W. H. Allen	E. C. Hulse
C. I. Bradley	William McMahon
J. E. Hale	J. C. Tuttle

PNEUMATIC TIRES FOR AIRPLANES

W. H. Allen	C. I. Bradley
W. M. Britton	William McMahon
Burgess Darrow	J. C. Tuttle

SOLID TIRES

W. H. Allen	Lawrence R. Davis
C. I. Bradley	Hugo Hoffstaedter
W. M. Britton	J. E. Hale

A. Hargraves

PNEUMATIC TIRE RIMS

W. H. Allen	C. N. McFarland
W. N. Booth	William McMahon
C. C. Carlton	A. W. Richards
Burgess Darrow	J. G. Swain
Lewis Fine	J. H. Wagenhorst

SOLID TIRE BANDS AND RIMS

W. H. Allen	J. E. Hale
W. N. Booth	A. Hargraves
C. C. Carlton	C. N. McFarland
Lawrence R. Davis	O. W. Mott
Lewis Fine	G. S. Porter

A. W. Richards

GOOD ROADS

TODAY there are in the United States 2,500,000 miles of rural roads, 12 per cent of which are classed as improved. A conservative estimate would indicate that not more than one-fourth of 1 per cent of the total mileage is suitable for motor truck trunk highway traffic. Indications point to a rapidly developing sentiment and demand for the creation of a system of interstate highways aggregating between 50,000 and 150,000 miles which shall be constructed and maintained under the supervision and at the expense of the Federal Government.

As in the case of many public activities, it is practicable in connection with this problem to derive valuable suggestions from practice in foreign countries. A review of their histories indicates that they have passed through the same transition period which we are entering. In France, many years ago, the people and the servants of the people realized the advantages accruing from the establishment of a permanent organization of efficient, well-trained highway engineers, and hence there was created the renowned Department of Roads and Bridges of France. Passing across the English Channel, we find similar conditions in Great Britain. To secure a dollar's worth for every dollar expended the British public realized that it was necessary to have in control of their public works men trained in a profession dealing directly with every economic and engineering phase of public improvements. It has therefore inaugurated the practice of requiring that applicants for a given municipal or county position shall have attained the grade of membership in the Institution of Civil Engineers of Great Britain commensurate with the responsibility of the work of the particular office.

Today between 5,000,000 and 6,000,000 motor vehicles use our highways, 10 per cent of which are motor trucks. Instead of constituting practically 100 per cent of the traffic, as in 1903, horse-drawn vehicles at present amount to 5 to 20 per cent on highways outside of urban districts.

Dependent upon the amount and character of the traffic to which a trunk highway will be subjected during the life of its surface and other factors influencing its selection, the following types are suitable: Bituminous concrete, cement-concrete, brick, and stone block.

Reviewing the construction of the past few years of the types of pavement mentioned used on trunk highways, it is found that the widths vary from 12 to 18 ft., with a few instances of greater widths. The Highway Committee of the American Society of Civil Engineers recommended several years ago that where motor trucks form a considerable portion of the total traffic likely to use a highway, the unit width of traffic lines should be considered as 9 or 10 ft. instead of 7 or 8 ft. as heretofore. In 1908, the first International Road Congress, held in Paris, adopted this resolution: "There should be but one roadway for every kind of vehicle, 19 ft. 8 in. wide at least." Many of the main county highways of England have an improved surface of from 20 ft. to 22 ft., and the main trunk highways of France are practically 24 ft. in width. It is obvious that our important interstate and intrastate trunk highways should have a roadway width of not less than 20 ft.

Some method must be devised by which the legislatures shall annually appropriate sufficient funds to maintain improved highways economically and properly. Legislature after legislature has followed the procedure of discounting the estimates submitted by highway departments. Hundreds upon hundreds of miles of highways are today improperly maintained due to lack of funds.

—Arthur H. Blanchard in *Motor Travel.*

ACTIVITIES OF S. A. E. SECTIONS

THE Metropolitan Section participated on March 26 in a cooperative meeting of all engineering interests in the Metropolitan District. This session, held in the Engineering Societies Building and known as an Engineers' Rally, was convened under the auspices of the New York sections of the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers and the S. A. E. Metropolitan Section. The subject was "The Engineer in Public Life." In addition to the members of the three societies mentioned, the discussion was participated in by members of the American Society of Civil Engineers and the American Institute of Electrical Engineers. A number of topics bearing on this general subject were discussed, including the civic responsibilities of the engineer and his relation to legislation, administration, public opinion and production and distribution.

On April 9 a joint meeting of the New York Section of the American Society of Mechanical Engineers and the Metropolitan Section was held at the Automobile Club of America. This was a symposium on the heavy oil engine and papers were presented on the subject of adapting the fuel to the engine as compared with adapting the engine to the fuel, and on the scope and limitations of present designs of heavy oil engines with special reference to their application to various classes of service. The general conclusion of all the speakers was that the oil engine is a success when given proper attention, and that an opportunity was overlooked by the Shipping Board in not going into extensive production of motorships during the war.

J. H. Hunt, experimental engineer of the Dayton Engineering Laboratories Co., presented a paper which was in part an outline of the fuel situation from the automotive engineers' point of view and a résumé of the experiences of his company in seeking to divert the attention of manufacturers, dealers and users, when poor operating conditions were encountered, from the ignition system to the real seat of the difficulty in the fuel tank. Meeting the needs of the situation created by the deterioration of the quality of the fuel makes it necessary to solve the four basic problems of starting, carburetion and distribution and burning of the mixture. The work done by the Dayton Engineering Laboratories Co. in this connection was brought out.

An analysis of the fuel situation was given by Dr. Charles E. Lucke, dean of the mechanical engineering school, Columbia University, who presided at the meeting. He called attention to the fact that the massive slow-speed, heavy-duty engines costing a large amount to build and install, and used in comparatively small numbers, could be operated advantageously on fuel which costs about one-fifth as much as common automobile fuel at the present time. On the other hand, the light popular automobile engine, which is much cheaper, uses a fuel that is comparatively rare and costly, and is very sensitive to changes in composition. Many factors serve to complicate the question of adapting the engine to the fuel or the fuel to the engine. Dr. Lucke pointed out that if an engine were developed to run on the cheapest fuel it is possible to produce, as soon as this engine was used to any extent the chemist would bring out a slightly better fuel for the same engine which would cost considerably more.

J. T. Smootz of the Bureau of Mines spoke of some of the problems of the chemists in their efforts to keep pace with the increased demand for gasoline, and gave some recent production figures.

A paper by A. H. Goldingham called attention to the reliability of the present hot-surface type of engine and attributed such performance to the more thorough atomization due to efficient spraying devices and pumps, improved construction of the vaporizing chamber, vaporizing lamp and lubrication of the parts. At the present time engines of this type are being built in sizes from 10 to 400 hp., the largest cylinder without piston cooling being 21 in. in diameter with a piston speed of 900 ft.

The application of the heavy Diesel engine to marine practice was treated in a paper by T. O. Lisle, editor of *Motorship*, who thought that the engine had not had a fair trial in the ships of the Emergency Fleet, which were in most cases under-powered, thus resulting in a constant overload being placed on the powerplant. Inexperienced labor also had something to do with the trouble encountered in this regard. He also referred to a motor cargo ship laid down by the British Admiralty during the war which was over 400 ft. long, had two engines with a total of 6000 hp. and was designed to attain a speed of 15 knots; as well as to a 4000-hp. six-cylinder land engine which had been constructed by Sulzer Bros. and was running in France. In the discussion which followed the last paper it was brought out that the troubles encountered by the Diesel engines installed in wooden ships on the Pacific coast were due primarily to the ships themselves.

William Kidder of Curtiss Aeroplane & Motor Corporation was the speaker at the meeting of the Minneapolis Section on April 9. His subject was "History and Development of the Airplane."

On May 7, P. E. Nelson of the Minneapolis Steel & Machinery Co. will present a paper on "Tractor Sales and Service" to the Minneapolis Section.

The April meeting of the Buffalo Section was held on the 16th. Francis W. Davis, assistant chief engineer of the Pierce-Arrow Motor Car Co., presented a paper on "Some Phases of Truck Transportation."

The Pennsylvania Section held a meeting on April 24. Ray Vance, director of Brookmire Economic Service, gave a talk on what the immediate future holds for the automotive industries.

At the March meeting of the Cleveland Section, held on the 28th, the speaker was C. W. Douglas, chief engineer of the Glenn L. Martin Co., who outlined some of the possibilities of the airplane. At the April meeting of the section, held on the 18th, Walter C. Baker, consulting engineer, Standard Parts Co., presented a paper on "Determining the Correct Location of Brake Levers."

The April meeting of the Detroit Section was held on the 25th. A paper on "Tractor Engines" was presented by H. L. Horning, general manager, Waukesha Motor Co.

During May, on a date to be determined, probably the 21st or 23d, the Detroit Section will hold a meeting at which W. T. Fishleigh will have as a subject "An Automotive Nation and Its Prime Demands Upon Manufacturer, Engineer and Educator."

At the Mid-West Section meeting to be held May 9, William B. Stout will be the speaker, his subject being "New Aircraft Development."

During the session of the Mid-West Section held on the 11th, discussion was continued of the paper presented at the January meeting of the Society in Chicago, by J. D. Nies on "Possibilities of Steam Power." Charles W. Dake, chief engineer of the Pyle-National Co., spoke on "Steam Turbines." W. J. H. Strong of the Strong Engineering Co. told of plans developed for the Government in connection with steam powerplants for airplanes.

PERSONAL NOTES OF THE MEMBERS

H. W. Alden, who has had charge of tank engineering work in the engineering bureau, Ordnance Department, has been discharged with the rank of lieutenant-colonel. He will resume his duties as vice-president and consulting engineer of the Timken Axle Co., Detroit, Mich.

Charles V. Bacon, who has been serving as assistant chief of the Division of Investigation, Research and Development, General Engineer Depot, with the rank of captain, has been promoted to the rank of major and appointed chief of the research section, engineering and standardization branch, purchase, storage and transfer division, General Staff. He has also been appointed Army representative to cooperate in the standardization of paint for all government organizations.

Victor N. Barton has resigned as mechanical engineer, Bureau of Aircraft Production, to accept the position of sales engineer with the Duplex Engine Governor Co., Brooklyn, N. Y. He will represent the company in Pennsylvania and the Southern States.

Joseph Berge, who was formerly manager of the aircraft division of the Champion Ignition Co., Flint, Mich., has been appointed chief engineer of the company.

George T. Briggs has joined the staff of the Sinclair Refining Co., Chicago, Ill., and will have charge of the sale of oil for lubricating internal-combustion engines. For the past 11 yr. he has been sales manager of the Wheeler-Schebler Carbureter Co., Indianapolis, Ind.

B. J. Cline has resigned as general superintendent of the aeronautic division, Nordyke & Marmon Co., Indianapolis, Ind., and vice-president and director of manufacturing in the Supreme Motors Corporation, Cleveland, Ohio, to accept the position of factory manager for the Templar Motors Corporation, Cleveland.

R. E. Clingan has resigned as Western branch sales manager of the Hess-Bright Mfg. Co., with offices at Cleveland, Ohio, and has been appointed sales manager of the Bock Bearing Co., Toledo, Ohio.

George M. Cohn, designer for the Chevrolet Motor Co., New York City, has had his name changed to George M. Corbin.

Edward Dixon has resigned as production manager and supervising engineer of the Oneida Motor Truck Co., Green Bay, Wis., and accepted a position in Chicago.

J. E. Duffield, who was formerly general manager and treasurer of the Bailey Non-Stall Differential Corporation, Chicago, Ill., has been elected vice-president and director of sales of the Essenkay Products Co., also of that city.

George W. Dunham, vice-president of the Militor Corporation, has been elected vice-president of the Militor Motors Co., New York City, which has been formed as a result of the merging of the Knox Motors Co., Springfield, Mass., and the Militor Corporation, New York City.

A. W. Frehse is now connected with the Detroit Pressed Steel Co., Detroit, Mich., as an engineer in the wheel division. He was formerly in the engineering division, Motor Transport Corps, holding the rank of captain, and did considerable engineering work in connection with the Class A and AA military trucks.

A. H. Gfrorer has accepted a position as engineer with the Automatic Transportation Co., Buffalo, N. Y.

H. A. Goddard has been appointed sales and advertising manager of the Militor Motors Corporation, Jersey City, N. J. He was formerly Michigan representative of the Standard Parts Co., with offices in Detroit.

James Guthrie, who has been serving as engineering manager of the Michigan District, Ordnance Department, with the rank of major, and offices in Detroit, has returned to Cleveland, Ohio, and resumed his consulting engineering practice, which he laid aside at the beginning of the war.

E. J. Hall has been discharged from the service of the Bureau of Aircraft Production with the rank of lieutenant-colonel, and has resumed his duties as vice-president of the Hall-Scott Motor Car Co., Berkeley, Cal.

Ralph S. Hayes has been discharged with the rank of first-lieutenant after 15 months' service with the motor and vehicle division, Quartermaster Corps and the General Staff, and has associated himself with the Pierce-Arrow Motor Car Co., Buffalo, N. Y.

M. L. Heminway has been appointed general manager of the Motor & Accessory Manufacturers' Association, New York City, succeeding L. M. Bradley, who has resigned.

L. H. Horner has been discharged from the Signal Corps with the rank of major, and resumed his duties as vice-president of the Acme Wire Co., New Haven, Conn.

W. S. Hovey, who was general manager of the Fairbanks-Morse Mfg. Co., and was stationed at the Beloit, Wis., plant, has been appointed vice-president in charge of manufacturing of Fairbanks, Morse & Co., and will now be in Chicago.

S. H. Hunter Kuenzel, who has been serving with the American Expeditionary Force in the Seventieth Field Artillery, has been discharged and has accepted the position of layout draftsman in the engineering department of the Premier Motor Corporation, Indianapolis, Ind.

Thomas S. Kemble has resigned his position as chief engineer and production manager of the motor division of the Curtiss Aeroplane & Motor Corporation, Buffalo, N. Y.

A. L. Kershaw has been discharged from the engineering division, Ordnance Department, with the rank of lieutenant, and has accepted a position with the Electric Auto-Lite Co., Toledo, Ohio.

Edwin H. Kottnauer has accepted a position with the Central Steel Co., and is now at the Chicago district sales office, Peoples Gas Building, Chicago, Ill.

R. A. Leavell, who has been serving as a member of the motor transport branch of the committee on education and special training, War Department, Washington, is now with the Clum Mfg. Co., Milwaukee, Wis.

Eric S. Locke has resigned as drafting-room foreman of the Hall-Scott Motor Car Co., Berkeley, Cal. He has made no plans for the immediate future.

Warren P. Loudon, who was engaged in cost-accounting work for the Signal Corps, has entered the employ of the Morgan Mfg. Co., Keene, N. H.

Dr. Charles E. Lucke, who during the war was director of the Navy Gas Engine School at Columbia University, New York City, has been released from Government service and resumed his duties as head of the department of mechanical engineering in the university.

Earle S. MacPherson has been discharged from the Air Service with the rank of captain, and for the present, at least, will remain in Paris.

James W. Macpherson, who was formerly connected with the inspection section, Signal Corps, and the Bureau of Aircraft Production, as an inspector of airplanes and airplane engines, has resumed his engineering studies at Cornell University.

T. J. Meachem has resigned as vice-president and general manager of the New Process Gear Corporation, Syracuse, N. Y., and has been elected president of the Meachem Gear Corporation, also of that city.

R. B. Morton has resigned as chief engineer of the Lenox Motor Car Co., Boston, and has been appointed tractor engineer of the Nelson Blower and Furnace Co., also of that city.

R. L. Notman, secretary of the Militor Corporation, has been appointed second vice-president of the recently organized Militor Motors Co., New York City.

H. F. Patterson has severed his connection with the Continental Motors Corporation, Detroit, Mich., and is now with the Rutenber Motor Co., Marion, Ind.

R. J. S. Pigott has resigned as superintendent of the raw material department and consulting engineer of the Bridgeport Brass and the Remington Union Metallic Cartridge companies, Bridgeport, Conn., to become industrial engineer of the Bridgeport Chamber of Commerce.

H. P. Schade, who was president of the Gill Piston Ring Co., is now president of the Schade-Phelps Corporation, New York City, which has absorbed the former company.

Joseph Schaeffers has been appointed manager of the Dual Axle Co., Cleveland, Ohio.

Everett M. Schultheis has accepted a position as designer for the Premier Motor Corporation, Indianapolis, Ind. He was formerly engaged in standardization work for the aircraft production service at the plant of the Nordyke & Marmon Co. of that city.

R. C. Stuart has joined the organization of the Southern States Motors Corporation, Richmond, Va. He was formerly production engineer for the Mobile Shipbuilding Co., Mobile, Ala.

Edwin M. Sutherland has been released from active duty in the Navy and is now associated with the Willard Storage Battery Co., in its Chicago branch, as a sales engineer in the tractor division.

E. O. Sutton, treasurer of the Knox Motors Co., has been elected treasurer of the Militor Motors Co., New York City, which was recently formed by the merging of the Knox company with the Militor Corporation.

George W. Sweet has been discharged from the Motor Transport Corps with the rank of captain, and has been appointed national service manager of the Studebaker Corporation of America. He will make his headquarters at the main office of the company, in South Bend, Ind.

H. A. Tarantous, who has been acting as technical editor of *Motor* for the past 3 yr., has been appointed managing editor.

Gurdon L. Tarbox, formerly an engineer with the Standard Oil Corporation, Plainfield, N. J., is now located at Georgetown, S. C.

Fred I. Tone has resigned as chief engineer of the U. S. Ball Bearing Mfg. Co., Chicago, Ill.

G. A. Ungar is now technical manager and chief engineer of the SKF Administrative Co., New York City.

Edward P. Warner is now stationed at the research laboratories of the National Advisory Committee for Aeronautics, Langley Field, Hampton, Va.

John H. Weller has resigned as factory manager of the Templar Motors Corporation, Cleveland, Ohio, and has been appointed director of manufacture with the Herschell-Spillman Motor Co., North Tonawanda, N. Y.

Rudolph D. Wolff, who formerly held the rank of chief machinist in the aviation section of the Naval Reserve Force, has been discharged from Government service, and is now secretary and treasurer of the Liberty Battery Co., Chicago, Ill.

Ernest Wooler has resigned as engineer of the Chandler Motor Car Co., Cleveland, Ohio, to accept the position of chief engineer with the Cleveland Automobile Co., also of that city.

Applicants *for* Membership

The applications for membership received between March 29 and April 29, 1919, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABBOTT, PAUL W., chief inspector, Lincoln Motor Co., *Detroit, Mich.*

ASCH, B. M., president, Asch & Co., Inc., *New York City.*

BAILEY, CHARLES E., assistant sales and advertising manager, Templar Motors Corporation, *Cleveland, Ohio.*

BAKER, WILLIAM A., production agent, motors branch, motors and vehicles division, Quartermaster Corps, *Washington.*

BECK, RALPH F., assistant engineer, S. D. Waldon & E. H. Sherbondy, *Detroit, Mich.*

BECHTEL, GEORGE HARRY, consulting engineer, 4 Palmeira Ave., *Mansions Hove, Sussex, England.*

BEGGS, ALAN H., aviator, U. S. Naval Air Station, *Miami, Fla.*

BELKNAP, HERBERT P., general manager and secretary, Atlas Electric Storage Battery Co., *Greenville, Mich.*

BENEDICT, EDWARD L., mechanical department, Smith, Hinchman & Grylls, *Detroit, Mich.*

BERG, ROY E., editorial staff, *Motor Age, Chicago, Ill.*

BERNDT, ARTHUR, aeronautical mechanical engineer, Bureau of Aircraft Production, *Elizabeth, N. J.*

BLAIR, RALPH K., works manager, Brewster & Co., *Long Island City, N. Y.*

BRADLEY, CLIFFORD I., sales engineer and service manager, Fisk Rubber Co., *Chicopee Falls, Mass.*

BUCKINGHAM, EARLE, mechanical engineer, Pratt & Whitney Co., *Hartford, Conn.*

BUCKMASTER, ENSIGN B. S., United States Navy Gas Engine School, Columbia University, *New York City.*

CHADDERTON, SYDNEY S., lubrication engineer, Standard Oil Co., *San Francisco, Cal.*

CHAPMAN, FRANK C., chief engineer, Brewster & Co., *Long Island City, N. Y.*

CLARK, JOHN, draftsman, Dauch Mfg. Co., *Sandusky, Ohio.*

CLARK, JOSEPH E., motor transport engineer, Standard Oil Co., *San Francisco, Cal.*

CONHEIM, RICHARD J., president, Metals & Chemical Corporation, *New York City.*

COTNER, JOHN C., chief draftsman, Revere Motor Car Corporation, *Logansport, Ind.*

COY, J. B., engineering, Velie Motors Corporation, *Moline, Ill.*

CRESON, WILLIAM KNOX, tool designer, Nordyke & Marmon Co., *Indianapolis, Ind.*

CULLEN, THOMAS F., managing editor, *Automobile Trade Journal, Philadelphia, Pa.*

DASEY, PERCY JOHN, sales and research engineer, Blodgett Engineering & Tool Co., *Detroit, Mich.*

DAWSON, FREDERICK Y., research engineer, Naval Aircraft Factory, *Philadelphia, Pa.*

DE BOTHEZAT, GEORGE, scientific expert, National Advisory Committee for Aeronautics, *Washington.*

DE FLOREZ, LUIS, inspector of naval aviation construction, Bureau of Construction and Repair, Navy Department, *Washington.*

DELVIN, S. F., engineer, Olds Motor Works, *Lansing, Mich.*

DENGLER, CLIFFORD H., tool designer, Wright-Martin Aircraft Corporation, *New Brunswick, N. J.*

DIETZ, GEORGE J., JR., tool engineer, Lincoln Motor Co., *Detroit, Mich.*

DUFFY, CHARLES, automobile examiner, Police Department, 240 Centre St., *New York City.*

EHRLICH, LOUIS B., engineer, American Bosch Magneto Corporation, *Springfield, Mass.*

EISNER, HARRY, president, Eisner Lenk Co., *Boston, Mass.*

ENOS, LAWRENCE W., manufacturers' representative, Firestone Steel Products Co., Firestone Park, *Akron, Ohio.*

FORSTER, ALBERT A., designer of electrical apparatus, Splitdorf Electrical Co., *Newark, N. J.*

FRANKLIN, MILTON W., consulting engineer, Remy Electric Co., *Anderson, Ind.*

FREEMAN, TALBOT O., mechanical engineer, New Depature Mfg. Co., *Bristol, Conn.*

GILL, JOHN D., technical adviser, Atlantic Refining Co., *Philadelphia, Pa.*

GLACKING, C. E., apprentice, Sayers & Scovill, *Cincinnati, Ohio.*

GOVE, B. L., production engineer, Nelson Blower & Furnace Co., *Boston, Mass.*

GRAF, WALTER A., designer, Edward G. Budd Mfg. Co., *Philadelphia, Pa.*

GRAHAM, WALTER F., metallurgist, Spicer Mfg. Corporation, *South Plainfield, N. J.*

GRIFFIN, C. G., buyer of mechanical transport supplies, care of British War Mission, *New York City.*

GROVER, RAY, chief engineer, Le Roi Co., *Milwaukee, Wis.*

HARTSHORN, S. H., vice-president, engineering department, Stewart Hartshorn Co., *New York City.*

HEDGELAND, MARLEY C., designer, Warner Gear Co., *Muncie, Ind.*

HIBI, KATSUHARU, engineer, Mitsui Mining Co., Ltd., *Tokyo, Japan.*

HOWARD, FENTON L., chief engineer, B & W Mfg. Co., *Chicago, Ill.*

HOYT, CLARENCE L., experimental engineer, Hall Scott Motor Car Co., *Berkeley, Cal.*

HUGHES, VICTOR, designer, Packard Motor Co., *Detroit, Mich.*

JAHANT, CHARLES J., superintendent, General Tire & Rubber Co., *Akron, Ohio.*

JAY, FRANK, president, Stanley Motor Carriage Co., *Newton, Mass.*

JOHNSON, CLEON R., manager, Goodyear Tire & Rubber Co., *Akron, Ohio.*

JOHNSON, HAROLD E., engineering draftsman, U. S. Ball Bearing Mfg. Co., *Chicago, Ill.*

KEENE, CHARLES F., acting as Eastern representative, Ensign Carbureter Co., *Los Angeles, Cal.*

KRAMLICH, CHARLES W., JR., chief draftsman, U. S. Ball Bearing Mfg. Co., *Chicago, Ill.*

KRATZER, D. A., layout draftsman, Bureau of Standards, *Washington.*

KROESING, PAUL A. R., designer, Elgin Motor Car Corporation, *Argo, Ill.*

LINDENTHAL, ALBERT G., assistant engineer, motor test laboratory, Buick Motor Co., *Flint, Mich.*

LORD, JAY WILLARD, assistant to chief, maintenance division, Motor Transport Corps, *Washington.*

MCCAFFERTY, HAROLD J., draftsman, L. W. F. Engineering Co., *College Point, N. Y.*

MACDONALD, WALTER N., secretary and factory manager, Curtis Tire & Rubber Co., *Muskegon, Mich.*

MCKINNON, R. A., manager of production, McKinnon Industries, Ltd., *St. Catharines, Ont., Canada.*

MCMULLEN, EUGENE JOHN, sales promotion, Olds Motor Works, *Lansing, Mich.*

MAINLAND, JOHN, chief engineer, thresher works, Advance Rumely Co., *La Porte, Ind.*

MALLON, WILLIAM H., motor transport officer, first division, Army of Occupation, *Germany.*

MALYCHEVITCH, O., chief engineer, Lebendeff Motor Car Co., *Petrograd, Russia.*

MANSFIELD, W. M., designer, LaCrosse Tractor Co., *LaCrosse, Wis.*

MEYNCKE, NORMAN, salesman, Hudson Oliver Motor Co., *Buffalo, N. Y.*

MILLER, MAJOR REUBEN, JR., associate chief, engineering division, Motor Transport Corps, *Washington.*

MILLS, CHARLES G., assistant extension professor, New York State College of Agriculture, *Ithaca, N. Y.*

MOISSELLE, S. WILLIAM, technical instructor, Hudson Motor Car Co., *Detroit, Mich.*

MOODY, C. L., in charge of mold engineering department, Fisk Rubber Co., *Chicopee Falls, Mass.*

MURPHY, WILLIAM JOSEPH, master mechanic, Champion Ignition Co., *Flint, Mich.*

NEREN, CAPT. JOHN, editor, *Motor, New York City.*

OLIN, R. E., mechanical engineer, Smith, Hinchman & Grylls, *Detroit, Mich.*

OLIPHANT, ABNER C., mobile gun carriage section, artillery division, Ordnance Department, *Washington.*

PACKARD, WARREN, assistant engineer, Neulectric Automobile Transmission, *Cleveland, Ohio.*

POMEROY, LAWRENCE HENRY, (mail) Society of Automotive Engineers, 29 West Thirty-ninth Street, *New York City.*

RITZER, W. G., metallurgist, Salisbury Axle Co., *Jamestown, N. Y.*

ROBERTSON, LUKE, layout draftsman, Service Motor Truck Co., *Wabash, Ind.*

ROGERS, WILLIAM B., JR., directing editor, Motor Boat Publishing Co., *New York City.*

ROTHAUG, WALTER H., instructor, College of the City of New York, production engineer, Standard Aircraft Corporation, *Elizabeth, N. J.*

SANDERSON, W. F., experimental engineer, Electric Wheel Co., *Quincy, Ill.*

SHERBAUM, ARTHUR, toolmaker, Eisemann Magneto Co., *Brooklyn, N. Y.*

SIDDELEY, E. H., assistant works manager, Siddeley-Deasy Motor Car Co, Ltd, *Coventry, England.*

SLOUGH, FRANK M., electrical engineer and patent attorney, Stromberg-Carlson Telephone Mfg. Co., *Rochester, N. Y.*

SMILEY, HAROLD JOHN, engineer of tests, Hayes Wheel Co., *Jackson, Mich.*

SOSS, SAMUEL, general sales manager, Soss Mfg. Co., *Detroit, Mich.*

STOUGHTON, HARRY R., general superintendent, Ogden Mfg. Co., *Plymouth, Ind.*

STUMHOFER, CHARLES, designer, Salisbury Axle Co., Inc., *Jamestown, N. Y.*

SUGIYAMA, KAMEICHI, layout-man, Continental Motors Corporation, *Detroit, Mich.*

SULLIVAN, AMBROSE E., mechanical engineer, Holt Mfg. Co., *Stockton, Cal.*

SUTTON, CAPT. HARRY ALLEN, technical section, Air Service, McCook Field, *Dayton, Ohio.*

THOMAS, CHARLES P., foreman of materials testing laboratories, Reo Motor Car Co., *Lansing, Mich.*

THOMPSON, FRED. H., chief inspector, experimental section, Naval Aircraft Factory, *Philadelphia, Pa.*

TIPPETT, WILLIAM M., manager engine department, Sears Roebuck & Co., *Chicago, Ill.*

WALKER, JOHN, draftsman, International Motor Co., *New York City.*

WEIGOLD, ERNEST, chief draftsman, Dodge Brothers, *Detroit, Mich.*

WHITE, HARRY F., salvage expert, Bureau of Aircraft Production, *Chicago, Ill.*

WIDRIG, S. LYNN, metallurgist, Salisbury Axle Co., *Jamestown, N. Y.*

WILLIAMS, REG W., technical assistant, Snead & Co. Iron Works, *Jersey City, N. J.*

WIRTH, CHARLES ALBERT, chief inspector of ordnance, inspection division, Ordnance Department, care of Trego Motors Corporation, *New Haven, Conn.*

WHITELEY, JAMES, chief draftsman, Herschell-Spillman Motor Co., *North Tonawanda, N. Y.*

WOOD, CLARENCE P., chief engineer, L-W Laboratories, Inc., *Philadelphia, Pa.*

WOOD, HAROLD F., metallurgical engineer, Central Steel Co., *Massillon, Ohio.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 15 and April 15, 1919. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (Aff. Rep.) Affiliate Representative; (S. E.) Student Enrollment; (S. M.) Service Member; (F. M.) Foreign Member.

ALLING, CLAUDE R. (M) engineer, casualty department, Underwriters' Laboratories, Inc., 207 East Ohio Street, *Chicago, Ill.*

ARMITAGE, JOSEPH B. (M.) mechanical engineer, research laboratories, Aluminum Castings Co., *Cleveland, Ohio.* (mail) 3107 East Derbyshire Road.

ATWOOD, HARRY N. (A) Veneer Products Co., *Smithfield, N. C.*

BALDWIN, LEONARD C. (J) draftsman, H. J. Koehler Motors Corporation, Fourth Avenue and Ogden Street, *Newark, N. J.* (mail) 78 Parkhurst Street.

BELLE CITY MALLEABLE IRON CO. (Aff.) Racine, Wis. Representative: John H. Dwight, vice-president and general manager.

BLAKE CO., WHITNEY (Aff.) *New Haven, Conn.* Representatives: M. E. Chester, secretary; H. G. Green, sales manager.

BLANKMAN, LYNN V. (M) aeronautical engineer, United Aircraft Engineering Corporation, 52 Vanderbilt Avenue, *New York City.*

BOLD, GEORGE (A) machinist, Standard Oil Co. of New Jersey, *Bayonne, N. J.* (mail) 123 West Twenty-seventh Street.

BOSART, RUSSELL S. (S. E.) student, Purdue University, *West Lafayette, Ind.* (mail) 229 Fowler Avenue.

BURNSHAW, E. W., JR. (A) secretary, treasurer and general manager, Girard Automobile Co., 2314 Chestnut Street, *Philadelphia, Pa.*

BURROWS, CHARLES W. (M) consulting engineer, *Grasmere, Staten Island, N. Y.*

CASTOR, STEPHEN R. (M) chief draftsman, New Process Gear Corporation, *Syracuse, N. Y.* (mail) 253 Whittier Avenue.

CETRULE, JOHN (J) tool and gage inspector and instructor in technical mathematics, Wright-Martin Aircraft Corporation, Long Island City, N. Y. (mail) Y. M. C. A., 8 East Third Street, *New York City.*

CHURCH, E. SOUTHWORTH (M) 8 Ardmore Terrace, *West Newton, Mass.*

CONNELL, W. J. (A) president, W. J. Connell Co., 171 Massachusetts Avenue, *Boston, Mass.*

COSGROVE, ROWE HOLLICE (A) Supreme Motors Corporation, Warren, Ohio. (mail) 1901 Idlewood Avenue, *East Cleveland, Ohio.*

CROUCH, GEORGE F. (M) technical editor, Motor Boat Publishing Co., *New York City.* (mail) 2511 Sedgwick Avenue.

DAYTON MALLEABLE IRON CO. (Aff.) *Dayton, Ohio.* Representative: John C. Haswell, president.

DRAKE, BRIG.-GEN., CHARLES BRYANT (M) chief, Motor Transport Corps, *Washington.* (mail) 1909 S. Street, N. W.

DUDLEY, A. MANSFIELD (M) designing electrical engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. (mail) *Oakmont, Pa.*

EIDMAN, LIEUT. FRANK L. (S. M.) 15th Regiment, Aviation, U. S. Naval Training Station, Great Lakes, Ill. (mail) 933 Danielson Street, *North Bergen, N. J.*

ERNST, ROBERT S. (S. E.) student, Purdue University, *West Lafayette, Ind.* (mail) 427 State Street.

GEYER, HARVEY (A) superintendent plant No. 3, Dayton Wright Airplane Co., *Dayton, Ohio.* (mail) 1128 Wildwood Avenue.

GOFFIN, JOSEPH F. (F. M.) partner and manager, Goffin & Co., Bruxelles, Belgium. (mail) care of Belgian Purchasing Commission, 25 Madison Avenue, *New York City.*

GOTTSCHALK, LIEUT. PROSPER L. (A) senior inspector, motors and vehicles division, Quartermaster Corps, care of Sterling Motor Truck Co., *Milwaukee, Wis.* (mail) 230 Twenty-first Street.

GRIMMELSMAN, F. F. (M) general manager, Perfection Spring Plant, Standard Parts Co., Sixty-fifth Street and Central Avenue, *Clevcland, Ohio.*

GRUBBS, JAMES T., JR. (S. E.) student, Purdue University, West Lafayette, Ind. (mail) Box 204, *Greenwood, Ind.*

HARKLESS, M. J. (M) engineer, railroad department, Buda Co., *Harvey, Ill.* (mail) 15311 Turlington Avenue.

HARPER, CARL BROWN (J) acting chief, engineering section, aircraft division, Bureau of Construction and Repair, U. S. Navy, Washington. (mail) 217 John Street, *Elkins, W. Va.*

HEDRICK, G. H. (J) acting chief of aircraft and aircraft engines, Bureau of Aircraft Production, Pittsburgh, Pa. (mail) 2125 Milligan Avenue, *Swissvale, Pa.*

JAMISON, EDGAR (A) proprietor, Edgar Jamison Steel Co., 77 Natoma Street, *San Francisco, Cal.*

JOHNSTON, RODERICK L. (M) chief metallurgist, Toledo Plant, Doehler Die-Casting Co., *Toledo, Ohio.*

JUDSON, DWIGHT R. (A) department manager, Talcott Co., Hartford, Conn. (mail) *Silver Lane, Conn.*

KEPPERLEY, JAMES E. (A) vice-president and general manager, Willys-Overland Co., *Toledo, Ohio.*

KING, C. F. LAWRENCE (M) consulting engineer, Cloverdale, 138 Bristol Road, *Birmingham, England.*

KNOWLES, EDWIN B. (A) general sales manager, Thermoid Rubber Co., *Trenton, N. J.*

LALLIER, ERNEST V. (M) instructor in engineering, Hebrew Technical Institute, 36 Stuyvesant Street, *New York City.*

LE BAR, GEORGE L. (A) supervisor, efficiency and time study department, Premier Motor Corporation, *Indianapolis, Ind.*

LEUTWILER, O. A. (M) professor of machine design, University of Illinois, *Urbana, Ill.* (mail) 511 West Green Street.

LOOP, J. F. (M) chief engineer, Graham Brothers, Inc., *Evansville, Ind.*

MACDONALD, H. P. (M) vice-president, Snead & Co. Iron Works, foot of Pine Street, *Jersey City, N. J.*

MACGREGOR, JAMES S. (M) materials engineer, United Aircraft Engineering Corporation, New York City. (mail) *Pelham, N. Y.*

MACKENZIE, DONALD (M) assistant physicist, Bureau of Standards *Washington.*

MAHONEY, E. H. (A) service technical expert, Nash Motors Co., *Kenosha, Wis.*

MARSH, EARLE S. (J) aeronautical mechanical engineer, Experimental Engineering Division, Bureau of Aircraft Production, *Dayton, Ohio.* (mail) 527 West Third Street.

MICHAEL, HERBERT BYRON (S. E.) student, Purdue University, West Lafayette, Ind. (mail) 1304 East Walnut Street, *Frankfort, Ind.*

NATIONAL DRAWN STEEL CO. (Aff.) Box 751, *East Liverpool, Ohio.* Representative: William H. Vodrey, acting secretary and treasurer.

NELLIS, CARL P. (A) superintendent, Dayton Wright Airplane Co., *Dayton, Ohio.* (mail) 1122 Haynes Street.

NISHIOKA, TOSHIO (M) resident engineer, Shibaura Engineering Works, care of General Electric Co., *Schenectady, N. Y.* (mail) 3 Ardsley Road.

NUTT, HAROLD (J) assistant chief engineer, gas engine department, B. F. Sturtevant Co., *Hyde Park, Boston, Mass.*

PETRIE, JOST W. (M) metallurgist, Premier Motor Corporation, *Indianapolis, Ind.* (mail) 2342 Park Avenue.

PURCHASE, FIRST-LIEUTENANT EDWIN K. (J) general staff, truck section, Motors Division, Munition Building, *Washington.*

QUINN, CHARLES J. (A) purchasing department, Curtiss Engineering Corporation, Garden City, N. Y. (mail) 181 Kingston Avenue, *Brooklyn, N. Y.*

RECKFORD, JOHN KING (J) assistant secretary, American Pencil Co., 220 Fifth Avenue, *New York City.*

RENTSCHLER, G. A., JR. (A) production engineer, Hooven, Owens & Rentschler Co., *Hamilton, Ohio.*

RICHIE, GEORGE E., JR. (A) superintendent of repairs, Autocar Sales & Service Co., 913 Jackson Boulevard, *Chicago, Ill.*

ROBBINS, HERBERT J. (M) sales engineer, Doehler Die-Casting Co., Toledo, Ohio. (mail) 10902 Lima Avenue, *Cleveland, Ohio.*

ROOT, H. M. (A) treasurer, Curtiss Aeroplane & Motor Corporation, *Buffalo, N. Y.* (mail) 217 Norwood Avenue.

SATTERTHWAITE, HARRY C. (M) chief tool designer, Premier Motor Corporation, *Indianapolis, Ind.* (mail) 3914 East Washington Street.

SCOTT, LEWIS L. (M) president and chief engineer, Standard Engineering Co., 4399 Chouteau Avenue, *St. Louis, Mo.*

SHERMAN, HAROLD C. (M) mechanical engineer, Packard Motor Car Co., *Detroit, Mich.* (mail) 464 Belvidere Avenue.

SINCLAIR, JAMES GLEN (M) chief engineer, Illinois Tractor Co., *Bloomington, Ill.* (mail) 710 East Monroe Street.

STERN, ALLAN G. (J) assistant physicist, Bureau of Standards, *Washington.*

SUMMERLEE, S. (M) tool supervisor, New Castle Plant, Maxwell Motor Co., Inc., *New Castle, Ind.*

TERRE HAUTE MALLEABLE & MFG. CO. (Aff.) *Terre Haute, Ind.* Representatives: F. R. Benson, president; H. L. Arnold, secretary and treasurer; L. M. Eyke, superintendent.

TOM, J. E. (M) chief engineer, Matthews Engineering Co., *Sandusky, Ohio.* (mail) 807 Tyler Street.

TORNEY, HENRY W. (M) industrial engineer and treasurer, Thomson-Torney Engineering Corporation, 253 Broadway and 51 East Forty-second Street, *New York City.* (mail) 51 East Forty-second Street.

TRUMBAUER, LLOYD S. (J) assistant chief draftsman, Vim Motor Truck Co., *Philadelphia, Pa.* (mail) 2617 North Bancroft Street.

UNION MALLEABLE IRON CO. (Aff.) *East Moline, Ill.* Representatives: J. L. Simmon, general manager, secretary and treasurer; James M. Sims, superintendent.

VAN SCOYOC, A. J. (M) factory manager, Kokomo Rubber Co., *Kokomo, Ind.*

VER PLANCK, W. EVERETT (M) ship propulsion division, turbine engine department, General Electric Co., *Schenectady, N. Y.*

WHARTON, JR., & CO., INC., WM. (Aff.) *Easton, Pa.* Representative: Karl Almquist, engineer.

WHITTINGTON, FREDERICK G. (M) chief engineer, Stewart-Warner Speedometer Corporation, 1826 Diversey Boulevard, *Chicago, Ill.*

WINCHESTER REPEATING ARMS CO. (Aff.) *New Haven, Conn.* Representative: Julian S. Gravely, head of laboratory division.

WISE, KARL M. (M) consulting engineer, American Engineering Associates 979 Woodward Avenue, *Detroit, Mich.*

ZURLINDEN, SERGT. WILLIAM W. (A) water service operator, utilities section, Quartermaster Corps, *Camp Dodge, Iowa.*

Book Reviews *for* S. A. E. Members

This section of THE JOURNAL contains notices of the technical books considered to be of interest to members of the Society. Such books will be described as soon as possible after their receipt, the purpose being to show the general nature of their contents and to give an estimate of their value.

THE GASOLINE AUTOMOBILE, Vol. III. By P. M. Heldt. Published by the author, Nyack, N. Y. Cloth, 5½ by 8¼ in., 410 pages. Price, $3.50.

This volume which is the third of the set on the design and construction of the gasoline automobile, by the same author, treats of the electrical equipment, its maintenance, care and repair. It is written mainly to meet the needs of automotive engineers and students of the science and art of automotive engineering, as was the purpose of the two preceding volumes. The method of treatment and the scope of the appeal of the present book differ, however, somewhat from these. It has been the aim of the author to incorporate in the book such material as would make it serve as a practical handbook for the large number of managers and employes of garages and service stations who have to take care of electrical apparatus. Sections on the maintenance, care and repair of different items of the electrical equipment are included, together with a statement of the elementary principles of electricity, and in dealing with these subjects the aim has been to make the information given capable of as wide application as possible and to explain the reason for defective operation and the remedies applied.

The book contains twenty-nine chapters and an appendix. Beginning with the elementary principles of electrical phenomena the reader is taken through the subjects of primary and secondary batteries, magnetism, electromagnetic induction and measuring instruments. Chapters on the various forms of ignition and the apparatus used in connection with it, such as magnetos, spark-plugs, generators, coils and combinations of the two are next treated. Wiring methods, storage-battery charging, testing of ignition apparatus and electric generators and their control are also covered. Lamps and fittings, starting motors and their drive and the care and maintenance of the batteries next receive attention. The appendix contains a number of S. A. E. Standards and Recommended Practices relating to this subject, as well as a set of specifications for headlamp tests and a copper wire table.

The material contained in the book is based on a series of articles which appeared in *The Horseless Age* in 1914 and 1915, but has been thoroughly revised and new material added. The book is profusely illustrated with drawings and photographs of the various forms of electrical equipment, as well as diagrammatic sketches and curves of test results.